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DEVELOPMENT OF A DISCRETE ADDRESS BEACON SYSTEM.(U)

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16. Abstract

This is the nineteenth Discrete Address Beacon System Quarterly Technical Summary covering the period 1 July through 30 September 1976. Included are the results to date of analytical studies, laboratory and flight experiments, and software developments supporting the concept feasibility and performance definition phase of the FAA DABS Program.

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DEVELOPMENT OF A DISCRETE ADDRESS BEACON SYSTEM

I. INTRODUCTION AND PROGRAM OVERVIEW

A. Introduction

This is the nineteenth Quarterly Technical Summary, covering work performed by Lincoln Laboratory between 1 July and 30 September 1976 to develop a Discrete Address Beacon System (DABS). This effort is supported by the Federal Aviation Administration through Interagency Agreement DOT-FA72-WAI-261 between the FAA and the United States Air Force.

DABS is an evolutionary upgrading of the present FAA ATC Radar Beacon System (ATCRBS) employing discretely addressable transponders and incorporating a ground-air-ground data link. DABS will provide the improved surveillance and communication capabilities required to meet the needs of an automated ATC system in the 1980's and 1990's.

Under Phase I, Lincoln Laboratory carried out a detailed system design of DABS based upon design studies, trade-off analyses, and experiments. This system design was described in a set of engineering requirements for engineering development models to be designed by the Sensor Development Contractor (SDC), and subsequently evaluated at NAFEC during Phase II of the DABS program. The completion of these requirements documents represented the nominal completion of Phase I.

During Phase II, Lincoln Laboratory is continuing to support the FAA as DABS System Engineering Contractor (SEC). Major areas of responsibility during this phase include: validation and refinement of the designs specified, assisting the FAA in monitoring the SDC, and using the DABS experimental facility to perform IPC flight tests.

B. Program Overview

Noteworthy DABS Program accomplishments during the report period were as follows:

(1) Data obtained using the TMF at a former NIKE site in Clementon, N.J., and at a Philadelphia Airport site were used to justify the procurement of property at the Clementon site for a future FAA ASR/Beacon site.

(2) Extensive measurements made in the LA area provided needed data on traffic density, fruit rates, near-airport site characteristics, and the present interrogator uplink environment. Surveillance data taped there during high-activity periods will become the basis of non-real-time IPC algorithm evaluation at DABSEF.

(3) Prototype DABS GA transponders were declared operational after a shakedown period which uncovered several performance problems.

(4) Completion of several BCAS design and performance analyses permitted the submission of formal Lincoln inputs to the active BCAS Engineering Requirement.

(5) Substantive DABS design aid was provided to Texas Instruments during numerous visits to Plano, Texas.

C. DABS Activity Précis

Sections of this Quarterly Technical Summary contain DABS Phase II task reports as follows:

Section II – Design Validation and Refinement. Installation of operational DABS transponders employing up-to-date DABS signal formats and protocols has permitted quantitative measurement of DABS link reliability in the presence of typical ATCRBS interference. Results of these measurements are shown.

Less than predicted reply reliability at modest range was traced to transponder malfunctioning due to faulty circuit design. Transponder retrofit will eliminate the problems described; revised specifications will ensure their absence in future transponders.

Examination of a large amount of scale-model and full-size (in-flight) aircraft antenna gain data, in the context of DABS system data rate requirements imposed by ATC and IPC, has led to unique criteria for airborne diversity (transponder dual antenna installations and switching). These criteria and the reasoning behind them, the flight regimes in which they apply, and the data necessary to apply them are discussed in Section II.

Section III – Environmental Characterization. A large data base continues to grow as data from the TMF and AMF field measurements are reduced and organized. These data, now permitting comparison of six distinct potential DABS sensor sites, include coverage efficiency, site-dependent monopulse error, false targets, traffic counts, and fruit levels. Data from the Philadelphia Airport and Los Angeles International Airport sites have been added this quarter. Figures and tables in Section III depict coverage, monopulse error vs azimuth, false target geometry, and track statistics for recent TMF sites.

Section IV – IPC Test and Evaluation. Emphases in the current IPC program at Lincoln are: (1) missions, flown by professional test pilots assigned to the IPC test program, to validate software embodying recent IPC algorithm changes based on the findings of earlier IPC flights; (2) missions, flown by subject pilots of varying experience and backgrounds, in which the system provides PWI information only (no positive or negative maneuver commands); and (3) preparation of a report covering flight test results to date.

Section IV briefly reviews the objectives of the present subject-pilot tests and discusses initial observations of subject-pilot reaction to PWI-only encounters.

Section V – Beacon (Based) Collision Avoidance System (BCAS). Section V includes a summary of an analysis of a proposed BCAS DABS reply processor, and predicts the effect and importance of error correction, dynamic thresholding, bit declaration, and confidence setting features. The "with/without processor feature" performance comparisons generated have influenced the Lincoln-recommended BCAS processor engineering requirements.

This section also details the functioning of active BCAS airborne equipment and describes the elements of the BCAS airborne hardware.

Since BCAS reply processing design requirements will ultimately be influenced by the degree to which air-air link signals are corrupted by air-ground-air multipath, quantitative multipath data are needed. Flights to gather this information have commenced, and this section presents data obtained thus far. Direct and earth-bounce returns for equi-altitude aircraft flying diverging paths over terrain and ocean are compared for transmission between top antennas and between bottom antennas.

Section VI – Aircraft Reply and Interference Environment Simulation (ARIES). Section VI describes the status of ARIES hardware and software development and notes the extent to which microprocessors are to be employed in the controller design. A feel for the action of the CAT and FAT controller logic is provided via flow diagram, and formats are defined for ATCRBS and DABS replies and for ATCRBS fruit.

Section VII – Experimental and Test Facilities. The broad types of data reduction support presently provided by DABSEF are outlined. Findings of the DABS transponder debugging program described are the basis for required transponder ER changes. TMF field experiments and time periods are noted, and notes regarding AMF usage, related operational problems, and future plans conclude this section.

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II. DESIGN VALIDATION AND REFINEMENT

A. DABS Link Performance Measurements

During July and August, a number of flights were made to determine DABS link performance in the heavily travelled corridor between New York and Philadelphia. In nearly all cases, the DABS-equipped aircraft flew a Riverhead-JFK-Robbinsville route or the reverse. The times of day for the flights were chosen to provide maximum downlink interference. In all cases, the aircraft were equipped with DABS transponders (Mod 4, Bendix) which were not locked out to ATCRBS interrogations. Only the bottom-mounted antenna was used. The sensor interrogation mode was DABS-only All-Call at a 57-Hz interrogation rate producing on the average slightly less than two mainbeam interrogations/scan.

1. Uplink-Reply Reliability

The reply reliability (Mainbeam Replies/Mainbeam Interrogations) for six "nominal" Riverhead-JFK-Robbinsville legs is shown in Fig. II-1. The flight path is shown in Fig. II-2. Detailed examination of the received replies revealed that the missing replies were due to the transponders failing to reply rather than to downlink interference. Reply reliability is therefore a characteristic of the uplink. Reply reliability, especially at close range, was lower than expected. Subsequent laboratory tests showed that the transponders suppress DABS replies after receiving ATCRBS P_1P_2 sidelobe suppression pairs. The suppression period lasts 35 μsec. Previous measurements indicate an uplink rate of approximately 3000 sidelobe interrogations/sec in the Philadelphia area. Given this rate and the above suppression characteristic, a reply rate decrease of 10.5 percent could be expected. DABS replies are also suppressed if the DABS uplink occurs while the transponder is replying to a legitimate Mode A or C interrogation or is in the following 15-μsec recovery period. For a mainbeam uplink rate of 600 ATCRBS interrogations/sec (measured previously), the DABS reply rate would decrease by an additional 2.1 percent.

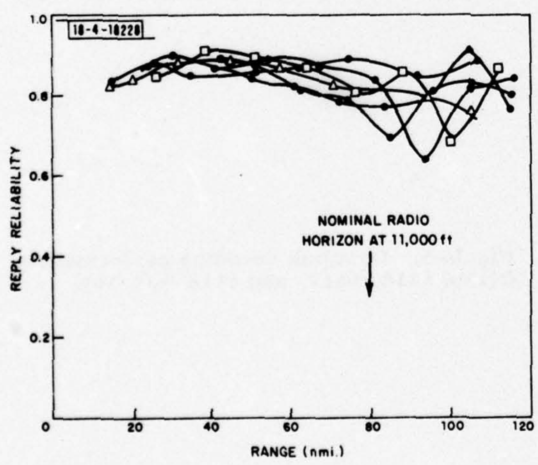


Fig. II-1. Reply reliability (mainbeam replies/mainbeam interrogations) for six Riverhead-Robbinsville flights.

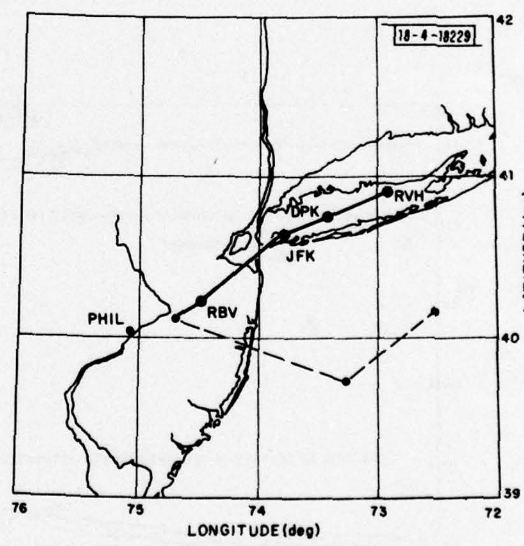


Fig. II-2. Flight paths for Riverhead-Robbinsville and overwater flights.

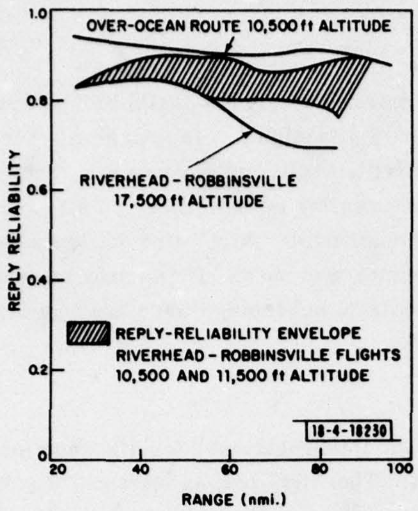
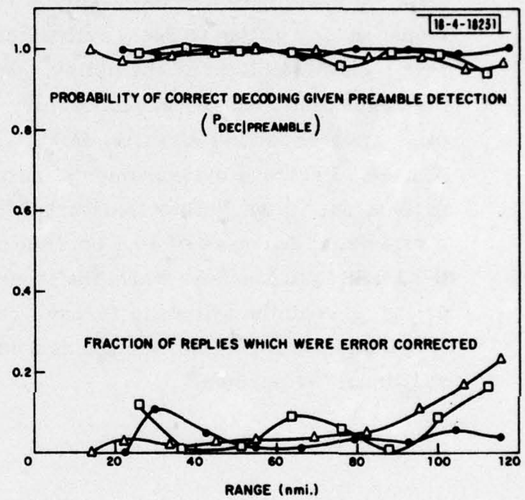


Fig. II-3. Effect of flight path on reply reliability.

Fig. II-4. Downlink decoding performance: flights 6113 parts 1 and 2, and flight 6113A (8/31/76).



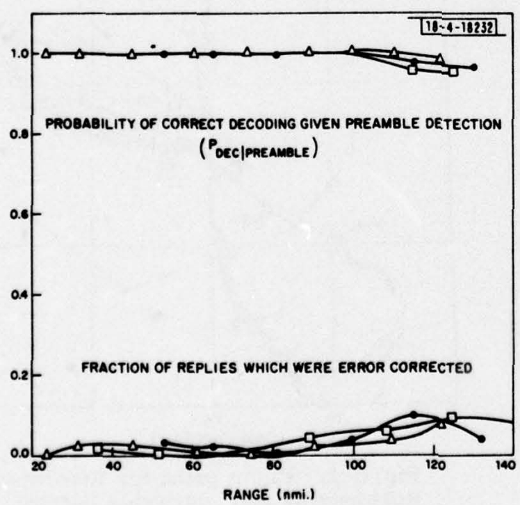


Fig. II-5. Downlink decoding performance: flights 6116, 6117, and 6118 (9/1/76).

These two effects would reduce the DABS reply rate by 12.6 percent, consistent with the data reported in Fig. II-1. The effect of flight path on reply rate was studied by flying a Robbinsville-JFK-Riverhead leg at a higher altitude (17,500 ft) and by flying a route over the ocean (at 10,500 ft) (see Fig. II-2). The reply reliabilities for these routes compared with the envelope of reply reliabilities for all the "nominal" legs are shown in Fig. II-3. Note that reply reliability for the high-altitude leg (where the aircraft is in view of a greater number of interrogators) is generally lower than the nominal envelope and that the over-ocean route has a higher reply reliability. These results are consistent with the uplink phenomena discussed above.

2. Downlink

The probability of correct decoding given preamble detection, i.e., given that a mainbeam reply is received, is shown in Figs. II-4 and -5 for two sets of flights. For the flights in Fig. II-4, $P_{\mathrm{decl\,preamble}} \geqslant 0.95$ for ranges up to 120 nmi with an average $P_{\mathrm{decl\,preamble}} = 0.986$ for the flights. For the set of flights in Fig. II-5, $P_{\mathrm{decl\,preamble}} = 1.0$ for all three legs for ranges up to 100 nmi. The error correction contribution to decoding is also shown in these figures. In general, error correction activity increases at long range where signal/interference is lowest. There are also additional peaks at shorter ranges due probably to peaks in azimuthal density of fruit.

3. Overall Link Performance

The preceding sections show that overall link performance is dominated by the uplink: when the transponder replies, the message will be, with very high probability, correctly decoded. Figures II-6 and -7 show the scan reliability (the probability that at least one reply per scan will be received and correctly decoded) for the two sets of flights shown in Figs. II-4 and -5. Table II-1 shows overall link statistics for all the Philadelphia DABS/TMF flights.

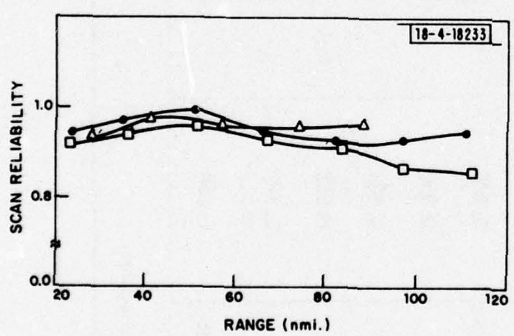


Fig. II-6. Scan reliability: flights 6113 parts 1 and 2, and flight 6113A.

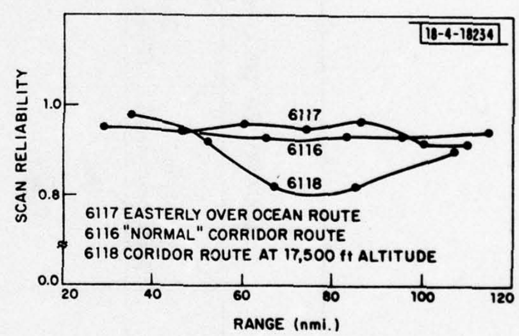


Fig. II-7. Scan reliability for three routes.

B. Airborne Diversity

A DABS design option has been whether or not to require airborne diversity, i.e., to require dual transponder antennas on certain classes of aircraft to ensure continuously available R-F

TABLE II-1

SUMMARY OF LINK PERFORMANCE FOR PHILADELPHIA DABS/TMF FLIGHTS

Flight	Replies per Interrogation	Correct Decode Given Reply Received	Correct Replies per Interrogation	Error Correction Contribution to Decoding	Correctable Messages not Decoded	Reports per Scan
6113	0.880	0.994	0.875	0.062	0.002	0.953
6113	0.879	0.995	0.875	0.038	0.0016	0.961
6113	0.861	0.993	0.855	0.024	0.0017	0.923
6114	0.859	0.992	0.852	0.0296	0.0016	0.963
6061	0.840	0.998	0.838	0.031	0.0021	Not DET
6062	0.830	0.998	0.828	0.019	0.0023	Not DET
6116	0.806	1.0	0.806	0.024	0	0.937
6017	0.852	1.0	0.892	0.012	0	0.950
6118	0.799	0.997	0.797	0.018	0.0027	0.907
Weighted* Average	0.854	0.996	0.851	0.030	0.0016	0.944

*By flight time per mission.

transmission for all flight attitudes. Consideration of the extent to which momentary blockage of signal transmission affects the performance of DABS and ATC automation has provided explicit criteria upon which to base this need. Separate criteria apply to normal flight (straight or turning, low rate of change of altitude) and takeoff flight conditions (sustained high pitch and angle-of-attack angles). The criteria do not apply to air-to-air links as contemplated for BCAS. The following subsections outline the reasoning and method used to reach these criteria.

1. Effect of Link Failure

Both DABS and IPC tolerate link failure on isolated scans and are logically structured to cope with multiple successive misses, but the seriousness of the problem increases rapidly with the number of misses. When an aircraft is turning (a time of severe antenna fade), the departure of the aircraft from the extrapolated track grows as time squared. Thus, two successive misses are in a sense four times as serious as an isolated miss. From the IPC point of view, in addition to the prediction of the conflict being four times poorer, data-link delays become very important, since the evasive action that can be taken by an aircraft also varies as the square of the time available.

2. Effect of Speed and Bank Angles

Nulls in aircraft antenna gain patterns are localized because they are caused by wings or wheels or tail section shielding. If an aircraft flies in a circle at some fixed roll angle, then fades occur for the most part continuously in one or, at most two, segments corresponding to the momentary shielding provided by a wing or tail section.

If the aircraft has a speed that causes it to traverse the circle quickly enough, it will only receive one interrogation while it is banking, i.e., in the excessive fade segment. If it spends more than four seconds traversing the faded segment, then two or more scans will be missed. Thus a relationship between how fast an aircraft flies, and how steeply it banks, must be included in the criterion for antenna diversity. This relationship is

$$P = \frac{3T \tan \Theta}{V}$$

where

V = aircraft velocity (knots)

Θ = roll angle, flying a coordinated circle (deg)

T = scan time

$$P = \begin{cases} \text{fractional segment of circle traversed in time } T; \\ \text{about 1 to 2 percent for aircraft in terminal areas} \end{cases}$$

3. Antenna Gain Patterns

Inspection of aircraft beacon antenna gain fluctuation data obtained using 11 scale-model aircraft and full-size aircraft in flight has revealed that the variation in downlink gain introduced by attitude can be represented to within about 2 dB by:

$$G(P, \Theta) = 1/2\,[I - \alpha(\Theta - 20)]\log(1/P)$$

TABLE II-2 CHARACTERISTIC VALUES FOR ANTENNA FADE		
Aircraft	I (dB)	α (dB/deg)
Piper Cherokee	−15.0	−0.28
Beech Baron	−20.0	−0.35
Beech B99	−18.0	−0.35
Grumman Gulfstream	−12.0	−0.28
Gates Lear Jet	−9.5	−0.33
Cessna 150	−11.5	−0.30
Helio U10D	−16.0	−0.37
Boeing 737	−10.0	−0.37
Boeing 727	−8.5	−0.45
Boeing 707	−11.0	−0.35
Boeing 747	−14.0	−0.40

TABLE II-3 DABS LINK POWER BUDGET	
Transmitter (800 W at DABS sensor RF port)	59.0 dBm
Sensor coupling loss	−1.5 dB
Sensor antenna gain – peak	26.0 dB
– elevation factor	−4.0 dB
Path loss – free space	−132.0 dB
– absorption	−0.5 dB
Aircraft antenna gain	0.0 dB
Received power (at antenna)	−53.0 dBm
DABS Minimum Usable Signal Level (MUSL at antenna)	−73.0 dBm
DABS fade allowance at 50 nmi	20.0 dB

where (assuming normal flight conditions):

P = cumulative probability of fade ($0.01 > P > 0.1$)

Θ = aircraft roll angle ($10 < \Theta < 30$ deg)

I = gain index ($-$dB) for a given aircraft at constant 20-deg roll angle

α = slope of gain vs roll angle characteristic for given aircraft.

For the 11 model aircraft tested, the values of I and α are as given in Table II-2. A value $\alpha = 0.35$ has been selected as typical.

4. A Criterion for Antenna Gain

Now, at a particular range, R, the quantity $G(P, \Theta)$ must, of course, not exceed the link fade margin, M, at that range for usable transmission. For DABS downlink parameters as shown in Table II-3, the link margin at 50 nmi is seen to be 20 dB, and the margin at any range determined from:

$$M = 20 \log \left[\frac{500}{R}\right] .$$

Thus, for $M + G(P, \Theta) \geq 0$:

$$I \text{ must be } \geq 0.35(\Theta - 20) - \frac{40 \log \left(\frac{500}{R}\right)}{\log \left(\frac{1}{P}\right)} . \qquad \text{(Eq. A)}$$

This expression is equivalent to the following statement expressed in physical terms: in order that a DABS-fed antenna(s), installed on an aircraft R nmi from the sensor and flying in a circle at bank angle Θ, provide a signal exceeding the usable threshold for a fraction $(1 - P)$ of the whole circle, the antenna must exhibit a gain index greater than or equal to I dB.

Using the aircraft bank-speed relationship developed above for link margin and antenna gain (Eq. A), we have

$$I \geq 0.35(\Theta - 20) - \frac{40 \log \left(\frac{500}{R}\right)}{\log \left(\frac{V}{3T \tan \Theta}\right)} . \qquad \text{(Eq. B)}$$

That is, an aircraft with antenna gain index $\geq I$ will not suffer multiple successive misses when flying as indicated by the parameters in the equation.

As an example, let:

$R = 60$ nmi

$T = 4$ sec

$V = 250$ knots

$\Theta = 20°$

then $I \geq -20.9$ dB.

For the case of a DABS sensor ($R_{max} = 60$ nmi, $T = 4$ sec) providing conflict detection and resolution characterized by (a) minimum interference with unstructured flight, and (b) last-ditch backup for failures in other services, Eq. B applies and the "Index greater than minus 20.9 dB" criterion holds.

For cases where conflict detection and resolution avails itself of flight intent (such as flight plan), or when necessary imposes sufficient structure temporarily (such as "don't turn" commands) – the usual case for sensors serving aircraft above 10,000-ft altitude and out to the 200-nmi range – Eq. A applies with $(1 - P) > 0.90$. Here the solution of Eq. A provides a diversity criterion of

$$I \geqslant -16.0 \text{ dB} \quad .$$

The above criteria would be applied by determining for a given aircraft single-antenna installation, the antenna gain value $[G(P, \Theta)]$ which is met or exceeded 0.99 of the time as the aircraft flies a circular path at 20 deg nominal bank angle. If this value exceeds −16.0 dB, the single-antenna installation is acceptable.

A decision regarding acceptability of this single-antenna installation during take-off conditions can also be made by similar measurements. This criterion will be discussed in a forthcoming issue of the DABS QTS.

III. ENVIRONMENTAL CHARACTERIZATION

A. Sensor Monopulse and Fade Characterization

Processing of circumferential flight measurements made at several TMF sites has continued this quarter. Measurement flights were carried out at the TMF/Philadelphia Airport site and the TMF/Los Angeles Airport site. At this point, the data from all TMF sites through Philadelphia Airport have been processed, and the LA data processing is in progress.

1. Software Improvements

Parallel work to improve the data processing computer programs has yielded new working software. The purpose of these modifications was to edit data from the track smoothing process and in some cases to edit data points from the data output. It had been found that ATCRBS synchronous garble, while rare, occurs often enough during these long missions to produce a noticeable amount of erroneous data in the final data summary formats. The new smoothing program recognizes these synchronous-garble effects by an outlier test. Instead of smoothing the data once as was done previously, the new program smooths the data four times, using a succession of three outlier tests with decreasing tolerances. Any points flagged by this process are removed from the smoothing, although not necessarily removed from the final data output. Judging from detailed examinations of program performance on erratic sections of data from the Philadelphia Airport mission, the new program separates good data from bad very effectively, locating a smoothed track in such cases where a human would locate it. The new program also has a "glitch elimination" feature which will delete certain wild points from the output. Here again, the program's glitch elimination performance has been found to be in good agreement with human judgment. Although the new program has been applied to the Clementon and Philadelphia data only, our plan is to freeze the program in this form and to reprocess the data from the earlier TMF sites using the new standardized software package.

2. DABS/TMF Performance vs Site

Site coverage quality at Philadelphia/Clementon site has been seen to be clearly better than at any of the other sites measured. Clementon is a hilltop site 260 ft above sea level, with clear horizon in all directions, unobstructed by the buildings, bridges, and other man-made objects that are found at a typical airport site, such as Philadelphia Airport. Results for Philadelphia/Clementon and Philadelphia Airport are shown in Figs. III-1 and -2. The monopulse bar graphs of Fig. III-1 and the monopulse coverage maps of Fig. III-2 present data in formats discussed in the previous DABS QTS. Similar plots for the Logan Airport site appear in that issue. The monopulse accuracy at the Clementon site is seen to be uniformly good over all azimuths and all elevation angles tested. On the other hand, the Philadelphia Airport site and the Logan Airport site both exhibit substantial monopulse error regions, particularly at low elevation angles.

Figure III-3 shows a "coverage efficiency" comparison among several TMF sites. Coverage efficiency, as plotted, is defined as follows. Suppose a monopulse tolerance T is adopted, such that coverage is considered to be "good" in regions of airspace where rms monopulse error $<T$, and elsewhere coverage is "bad." Then, taking as 100 percent the number of aircraft above zero elevation angle, coverage efficiency is the fraction of those aircraft located within the "good" coverage regions. As calculated here, coverage efficiency is simply the

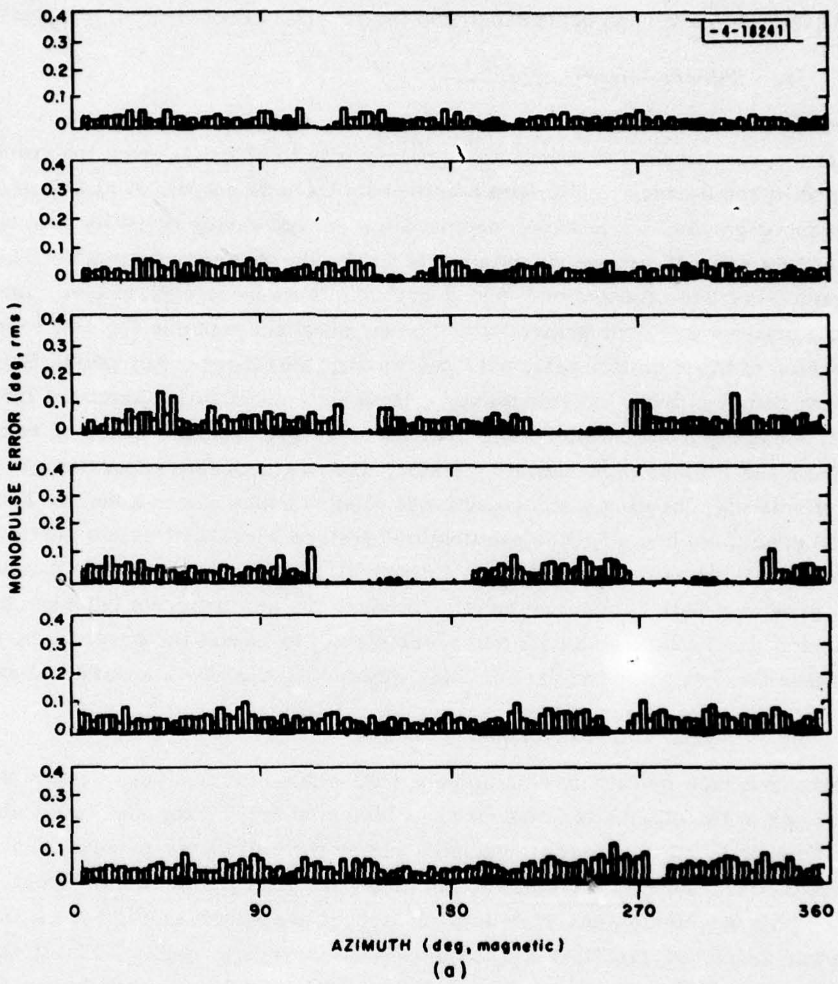


Fig. III-1(a). Monopulse error vs azimuth: Clementon, N.J.

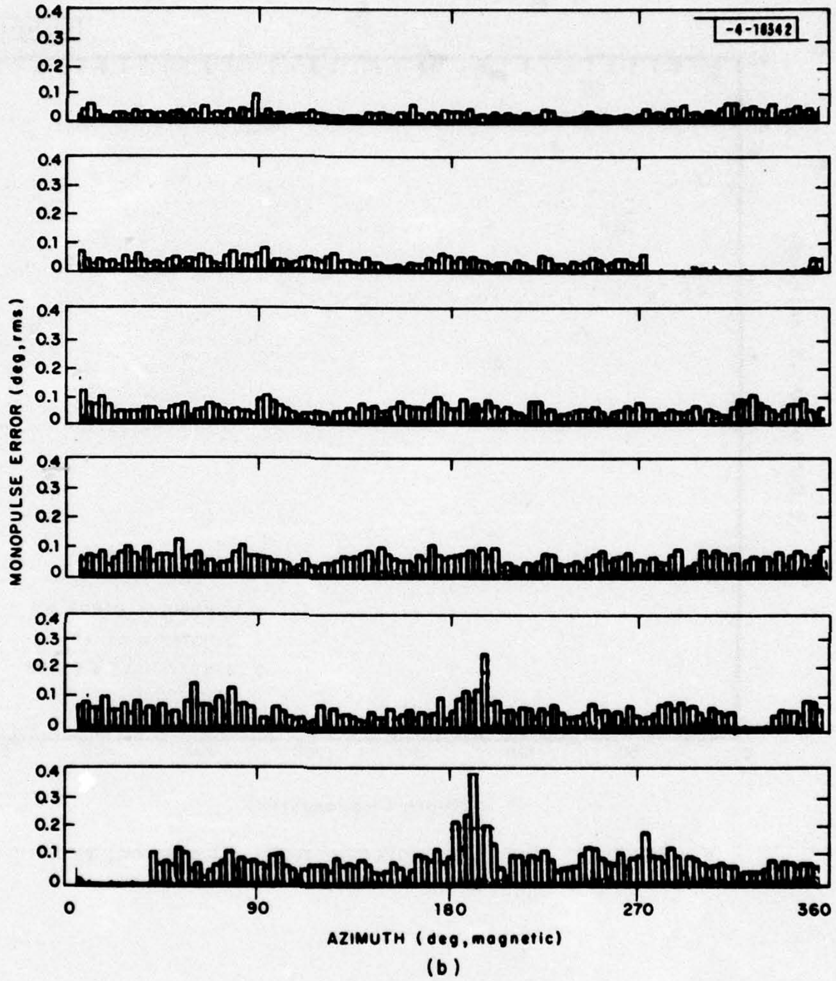


Fig. III-1(b). Monopulse error vs azimuth: Philadelphia Airport.

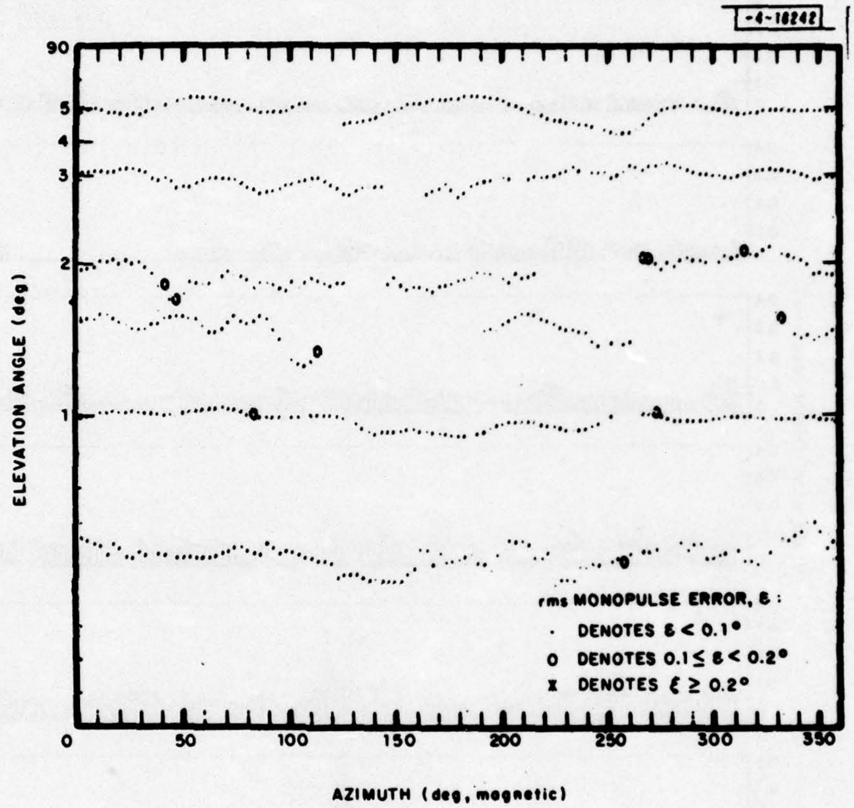


Fig. III-2(a). Monopulse coverage map: Clementon, N.J.

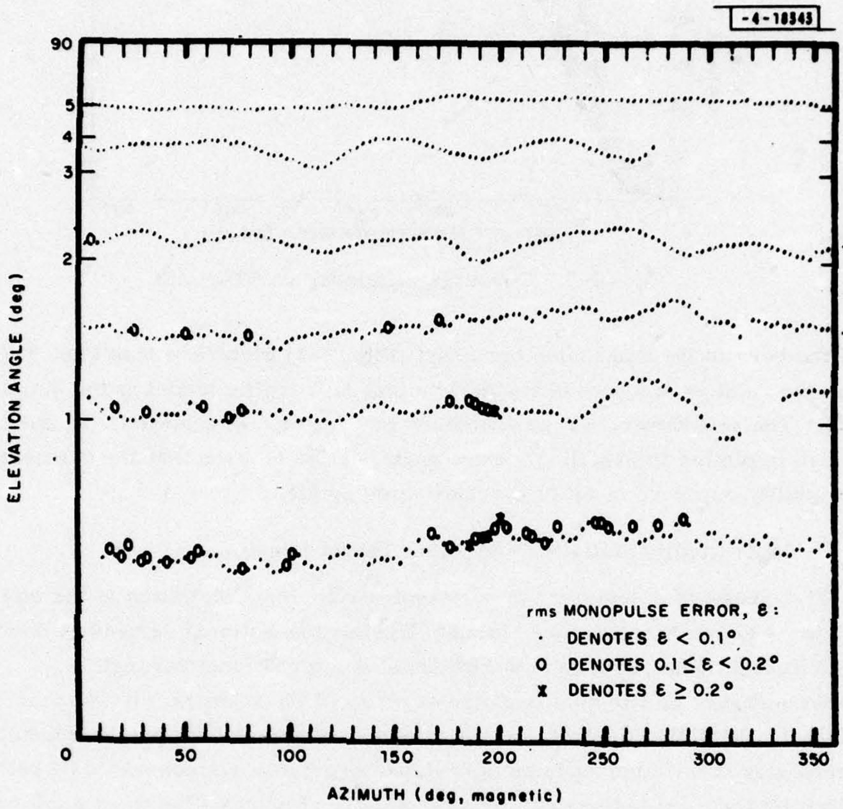


Fig. III-2(b). Monopulse coverage map: Philadelphia.

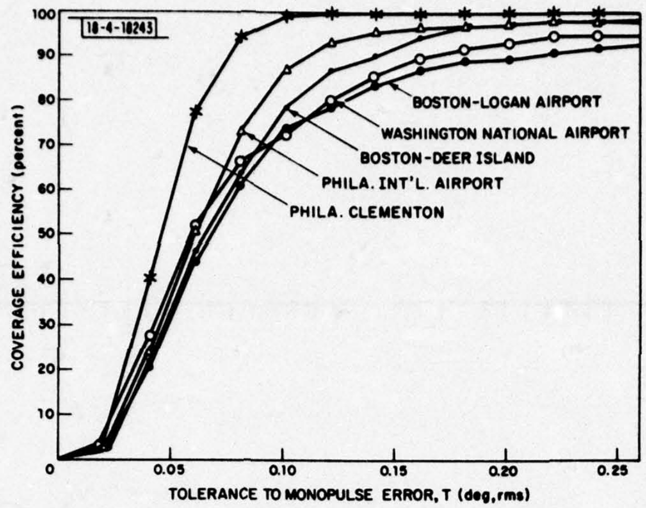


Fig. III-3. Coverage efficiency vs TMF site.

fraction of the bars in the monopulse bar chart (Fig. III-1) which are less than T (suitably weighted by the relative amounts of traffic in a standard traffic model at the six elevation angles tested). The resulting coverage efficiency is a function of tolerance T, and it is this function which is plotted in Fig. III-3. Here again, it can be seen that the Clementon site has the highest quality coverage of all of the TMF sites so far.

3. Track Quality Statistics and False Target Locations

Table III-1 presents a summary of pertinent environment statistics at the sites visited up to this quarter – Logan Airport, Deer Island, Washington National Airport, Clementon, N.J., Philadelphia International Airport, and Los Angeles International Airport.

A further measure of site quality is the severity of the false-target environment. This is characterized by the reflector program output which examines data from discretely coded aircraft and tabulates the number of false correlated target reports generated by reflectors, describing them by their azimuth extent and orientation. Figures III-4 to -8 show samples of false target reflectors from the various sites except Clementon, N.J., which did not exhibit any significant reflectors.

B. Ground-Air Link Characterization

AMF data reduction software will now detect and track individual interrogators, and measure their PRI's mode interlace patterns, stagger patterns, scan rates, and beamwidths. This software will perform these functions for interrogation repetition characteristics which are periodic, or have standard 3-pulse stagger, standard 5-pulse stagger, or standard 8-pulse stagger (ASR-7's). The interrogator track data make it possible to determine PRI timing drifts, and also allow interrogator antenna patterns to be plotted. Some examples of measurement results produced by these software programs follow.

TABLE III-1

FIELD SITE DABS PERFORMANCE SUMMARY

	Logan Int'l TMF 2090 2/26/76 13:10 EST Thursday	Deer Island TMF 3037 3/29/76 15:45 EST Monday	Washington National TMF 4010 5/12/76 09:17 EDT Wednesday	Clementon, N. J. TMF 5016 6/18/76 09:13 EDT Friday	Philadelphia Int'l TMF 6010 8/11/76 11:30 EDT Wednesday	Los Angeles Int'l TMF 7009 9/20/76 13:00 PDT Monday	Los Angeles Int'l TMF 7004 9/18/76 15:57 PDT Saturday	Los Angeles Int'l TMF 7017 9/26/76 15:00 PDT Sunday
Tracks Started								
Number	142	151	497	174	200	394	239	265
Average Length	59	96	53	62	38	67	77	42
Percent Target Reports								
With Valid Altimeter Code	59	48	76	75	54	63	29	38
Percent Target Reports								
With Brackets Only or on Ground	31	45	17	19	42	34	61	57
Percent Target Reports								
With No Mode C Response	10	7	7	6	4	3	10	5
Qualifying Tracks								
Number	56	73	276	74	84	270	141	142
Blip/Scan	0.99	0.99	0.97	0.99	0.99	0.97	0.98	0.97
Average Miss Length (Scans)	1.7	1.5	2.2	1.1	1.3	1.5	1.4	1.5

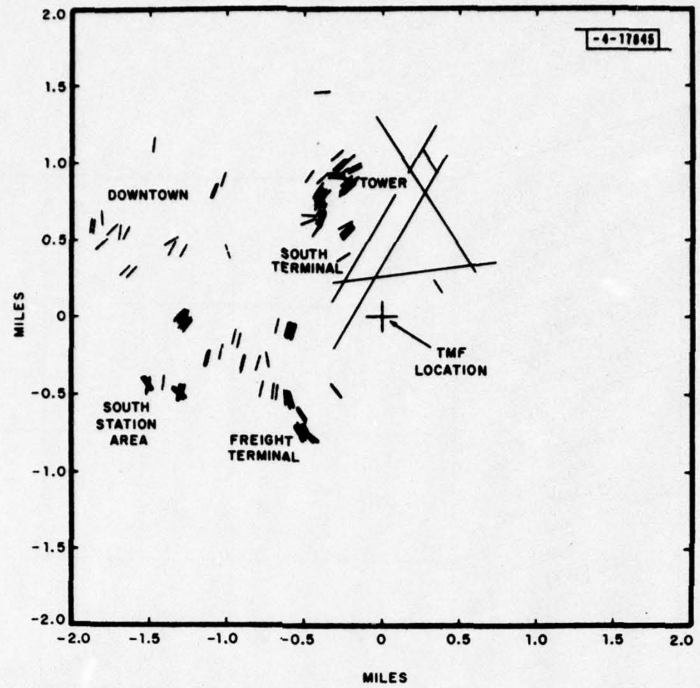


Fig. III-4. False targets within ±2 nmi: TMF at Logan Airport site.

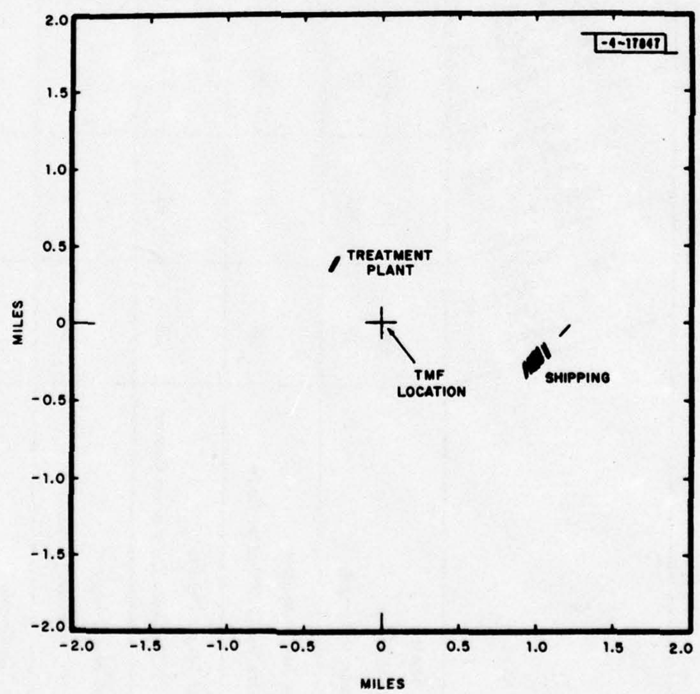


Fig. III-5. False targets within ±2 nmi: TMF at Deer Island site.

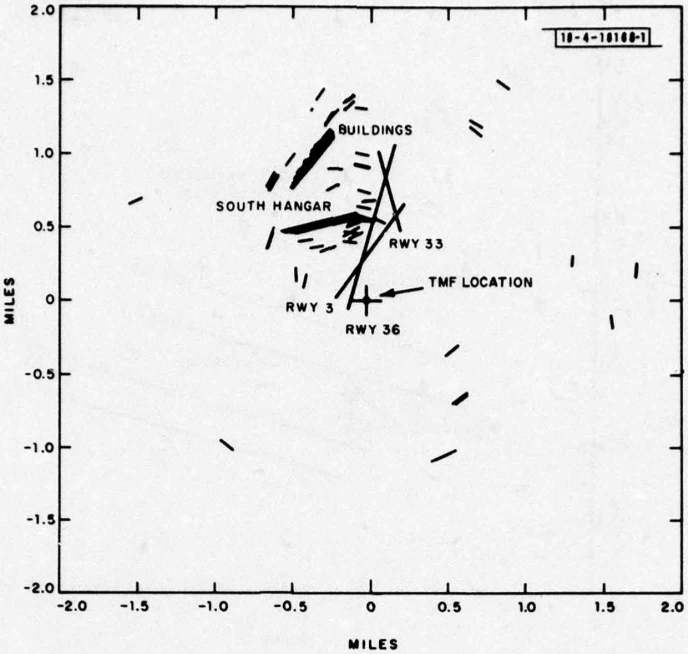


Fig. III-6. False targets within ±2 nmi: TMF at Washington National site.

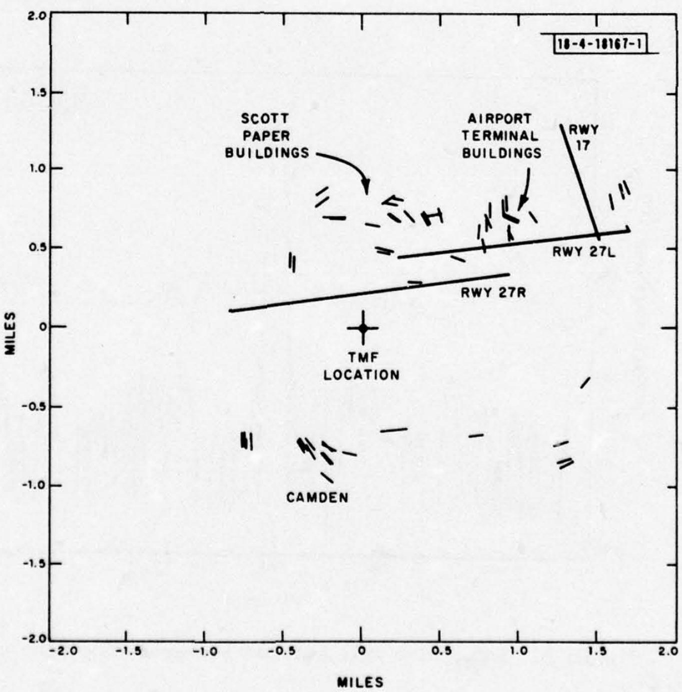


Fig. III-7. False targets within ±2 nmi: TMF at Philadelphia International Airport.

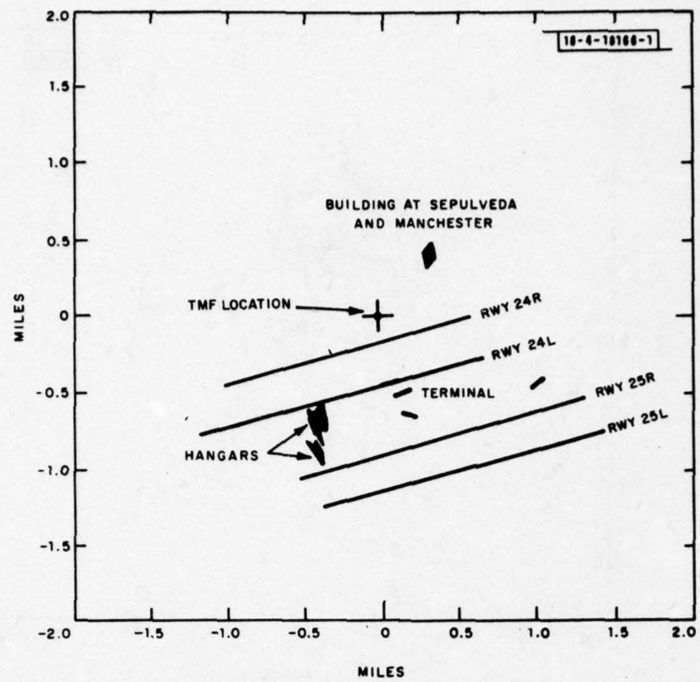


Fig. III-8. False targets within ±2 nmi: TMF at Los Angeles International Airport.

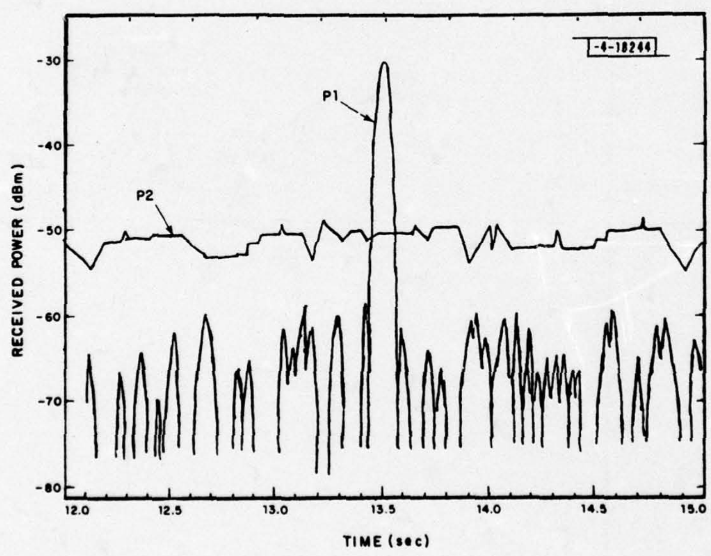


Fig. III-9. San Pedro Hill Antenna Patterns (one scan apart).

Figure III-9 shows the antenna patterns of the San Pedro Hill interrogator measured in flight, at a point 10 nmi SE of San Pedro Hill, at 7200 ft altitude. A 3-sec interval of time is shown around each mainbeam corresponding to 90° of antenna rotation. The plot shows the P1 pulse pattern and the P2 pulse pattern for two successive scans. The P3 pattern is not plotted as it was found to be essentially identical to the P1 pattern. From these data the following are observed. The directional antenna pattern is quite clean with sidelobes about 30 dB down. The agreement of P1 and P3 patterns implies that this interrogator does not employ improved SLS, contrary to the information provided in ECAC's file of ATCRBS/IFF interrogators. Also it is interesting to observe appreciable changes in both the P1 and P2 patterns from one scan to the next, during which time the receiving aircraft moved only about a half mile. On one of the scans, the received P2 power was relatively low, allowing sidelobe punchthrough at some points.

Figure III-10, consisting of two parts, shows some of the background of the uplink environment from which the San Pedro Hill data were gleaned. The top portion of the figure shows the mainbeams and occasional sidelobes of some 14 interrogators (see A = Long Beach, for example) simultaneously attempting to interrogate aircraft in the LA area. P3 pulse power is plotted vs time for a 30-sec interval.

The lower portion of the figure shows the corresponding PRI at which the interrogators (shown at the top) operate. A dot or small dash has been plotted under every mainbeam or sidelobe at the top. Since these interrogators have PRI which are different from the others, and are constant from mainbeam to mainbeam, each set of dots traces out lines parallel to the guidelines shown. If this were a player piano roll, each interrogator would be a single note on

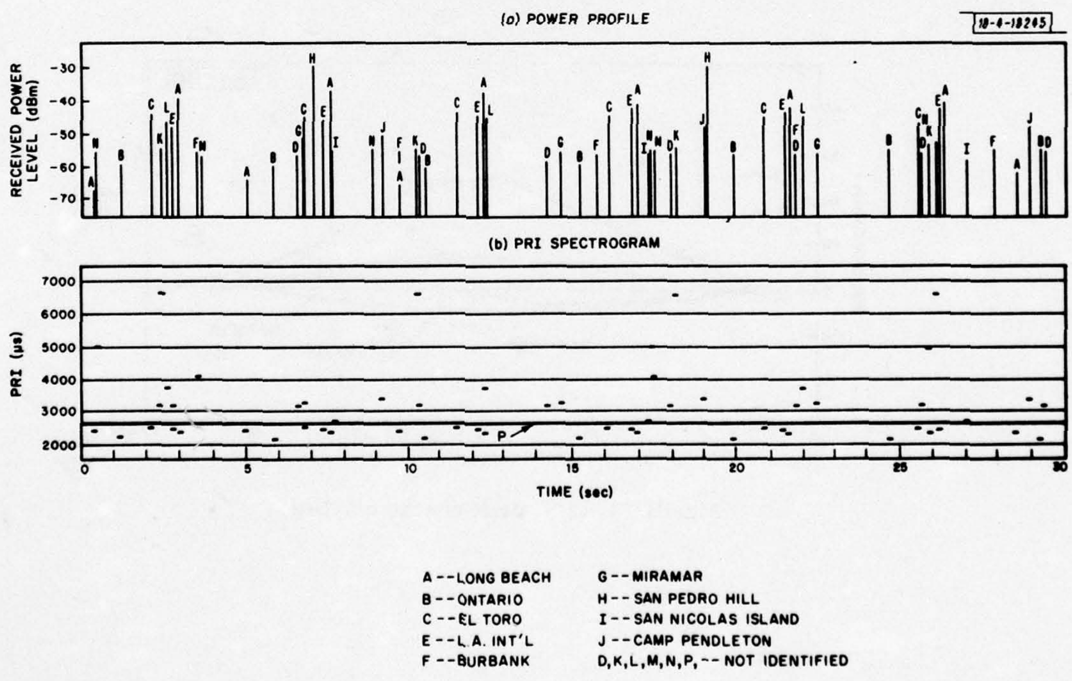


Fig. III-10. Power profile and PRI spectragram of LA uplink environment.

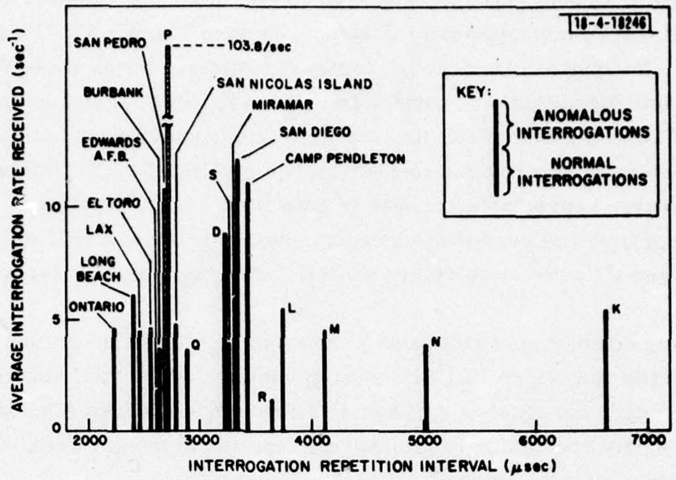


Fig. III-11. PRI spectrum.

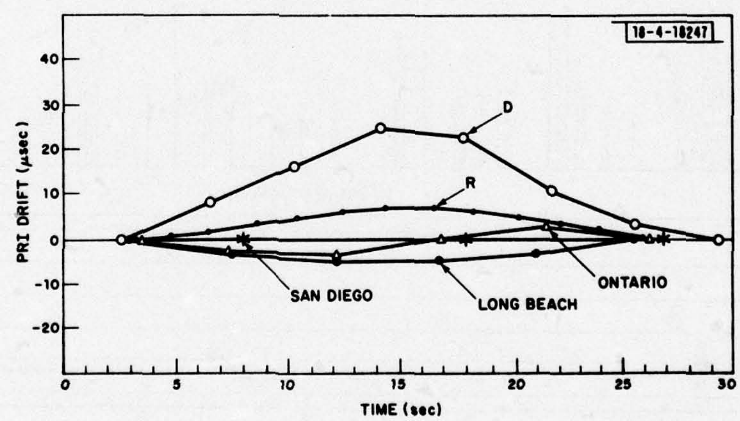


Fig. III-12. PRI drift characteristics.

the piano, played with a frequency corresponding to the scan time of the interrogator, the note itself being determined by the PRI.

Most of the interrogators are seen to behave as expected: interrogations bunched within mainbeams which scan by the aircraft periodically once every 4 to 12 sec, and with approximately the same peak power on successive scans. The two mainbeams of San Pedro Hill, 12 sec apart, are shown by the tallest lines at the top (called "H"), and the two dashes under these lines at the 2700-μsec level at the bottom. On the other hand, interrogator M is somewhat unusual having a 14-sec scan time. Interrogator P is quite unusual in that it does not seem to have a mainbeam. A closer examination has shown that indeed this interrogator transmits omnidirectionally.

Interrogator A (Long Beach Terminal) exhibits a non-ideal phenomenon in which a secondary bunch of interrogations is received about midway in time between passes of the primary mainbeam, and with about 27 dB less power. To distinguish between multipath and sidelobe interrogations as possible causes, the fine-scale time structure was studied. It was found that the secondary interrogations are received without any significant differential propagation delay, and that, therefore, sidelobe punchthrough is the most likely cause.

The PRI spectrum plotted in Fig. III-11 is broken into "normal" interrogations (those due to direct signals from the mainbeam) and "anomalous" interrogations (others due to multipath or sidelobe interrogation). It is seen that most interrogators produce about five interrogations per second on the average with almost all of these being normal interrogations. In a few cases, however, the anomalous interrogations are very numerous and may exceed the normal interrogations. Interrogator P, mentioned above, stands out on this plot as a contributor of an excessive average interrogation rate.

Figure III-12 shows the PRI stability of several of the interrogators tracked in this 30-sec recording. The PRI drifts plotted are relative rather than absolute, expressing the departures from a perfectly periodic pattern fitted to the received interrogations near the beginning and near the ending of the 30-sec recording. Certain of the interrogators are very stable in PRI; San Diego, for example, whereas others exhibit considerable drift. Interrogator D, for example, has a PRI drift from the first 15 sec to the last 15 sec of about 3 parts per million.

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IV. IPC TEST AND EVALUATION

A. Subject-Pilot PWI Tests

Tests are presently being conducted involving only the proximity warning feature of IPC. Pilot subjects fly the test aircraft on a given course and are given both the ordinary and the flashing PWI indications of proximate traffic. The interceptor conducts a series of near-miss approaches with the test pilot ignoring the IPC commands causing the subject to react to resolve the situation. Altitude separation is maintained for safety. Visual contact by the test pilots is a prerequisite for near-miss approach. The purpose of this testing is to determine pilot reaction to near-miss encounter situations. The procedure being followed is intended to:

(1) determine pilot's criteria for establishing intruder as a threat,

(2) determine pilot procedures in resolving conflicts,

(3) establish subject's utilization of proximity warning and his reaction to it,

(4) compare pilot's threat evaluation with IPC algorithm status, and

(5) compare pilot resolution strategy with IPC command resolution.

Seven proximity warning test missions involving 11 subjects have been completed. Some interesting and important issues have been identified during these tests. It has been observed that pilots reflect a sense of urgency when they receive the flashing PWI. Some pilots react by maneuvering their aircraft even though they have not attained a visual sighting of the intruder aircraft. Their rationale has been anything is better than staying on a collision course. However, in debriefing sessions, it has been pointed out that some of these random maneuvers have caused the situation to worsen.

These tests are pointing up the definite need for additional information beyond the proximity warning now being provided. Pilots have suggested alternate forms that this information should take. Additional proximity warning information on the threat such as altitude, range, and heading would be useful to augment the bearing and implicit altitude and range provided by IPC. Others have suggested that being told the direction to maneuver, the extent of the maneuver, and when to maneuver would be helpful.

Another observation made from these tests include the disparity between the pilot's threat estimation and IPC's.

The pilots using PWI information tend to wait longer to declare an intruder a threat on slow closing situations. IPC in these situations delivers commands, in some instances, long before the pilots react on their own. However, other tests have shown that the solution is not simply to decrease the algorithm threshold values. During some high-speed encounters and during most turning encounters, pilots have complained of the lack of time to evaluate the situation before commands are presented.

Many times the commands that IPC would have a pilot implement directly conflict with the pilot's resolution. One example: In slow overtake situations with aircraft coming together at shallow angles, pilots tend to hold course or make a slight maneuver to assure passage behind the traffic while always maintaining visual sighting of other aircraft. IPC directs both DABS/IPC pilots to perform turn-away maneuvers causing them to lose sight of each other and to make excessive turning maneuvers.

These and other observations are being quantified and prepared in report form.

B. IPC Flight Test Status

The statistics describing overall IPC flight test activity at Lincoln Laboratory from March 1975 through September 1976 are given in Table IV-1. (These statistics may be compared with like figures for the period through April 1976 given on p. 57 of the April 1976 DABS QTS.)

TABLE IV-1

IPC FLIGHT TEST STATUS

March 1975 – September 1976

Missions	107
Validation	47
Demonstration	20
Subject Pilot	40
Encounters	1334
Planned	1177
Unplanned	
Two Aircraft	130
Three Aircraft	27
Pilots	87
Test Pilots	4
Demonstration Pilots	24
Subject Pilots	59

V. BEACON COLLISION AVOIDANCE SYSTEM

A. BCAS Reply Processing Performance Analysis

1. Introduction

The performance of the DABS BCAS reply processor in the presence of ATCRBS fruit has been investigated by means of computer simulation. Fruit was modeled with Poisson-distributed arrival time, and the traffic was modeled uniformly distributed in area; average fruit per second was input as the mean of the Poisson distribution. The codes of the fruit replies were randomly chosen with the state of each pulse (0 or 1) being equally likely. A given signal level DABS BCAS reply was overlapped with the generated fruit and Gaussian noise and then run through a BCAS receiver and processed by the BCAS reply processor (which has error detection and correction capability).

Figures V-1, -2, and -3 are plots of the probability of successfully decoding the BCAS reply for various processing schemes. Probability of successful decoding is presented as a function of signal level for a fruit rate of 35,400 fruit per second exceeding a level of −70 dBm. This rate corresponds to the BCAS reply being overlapped by an average of three fruit replies (with signal levels in excess of −70 dBm). Data points used in generating these curves are the result of averaging 200 independent Monte Carlo trials. The results are conditioned on an MTL level of −75 dBm (not considering dynamic thresholding), a noise power of −95 dBm, and a 1.6-nmi range window about the leading edge of the BCAS preamble.

2. The Effect of Error Correction

The reply processing scheme analyzed in Fig. V-1 declares a message bit to be a 1 if the first chip (of the two-chip PPM format) has a larger amplitude value than the second chip and a 0 otherwise; this technique is referred to as amplitude-compare. Confidence setting is determined by obtaining a single video pulse quantizer (VPQ) sample from each chip. The bit confidence is set high if: only one of the two VPQ samples is a 1, and the 1 sample corresponds to the larger chip; otherwise, the bit confidence is set low. This is referred to as VPQ single sampling.

The dashed curve shown in Fig. V-1 shows the performance of the amplitude-compare/VPQ single-sampling scheme when error correction is employed; the solid curve corresponds to the case of no error correction. These curves were derived assuming a fixed detection threshold; i.e., no dynamic thresholding. The conclusion here is that for a given performance level, a protected reply can operate in up to twice the fruit environment as that for an unprotected reply, i.e., for a given fruit level, a target whose replies are protected can be acquired at 1.4 times the range as that for a target with unprotected replies. Based on this result, the proposed DABS BCAS system employs parity-protected squitters. Since there is no need to correlate several squitter replies to validate the target's ID, squitter protection also results in less squitter processing and a further decrease in acquisition time.

3. The Effect of Dynamic Thresholding

Dynamic thresholding is used in the BCAS system to provide protection against the effect of multipath on message processing. The simulation has shown that the dynamic threshold should be set ≈6 dB below an amplitude estimate derived from the BCAS DABS preamble; this value provides reasonable protection against the effect of multipath while minimizing message processing performance degradation for low-level signals. In particular, it was learned that a −6-dB

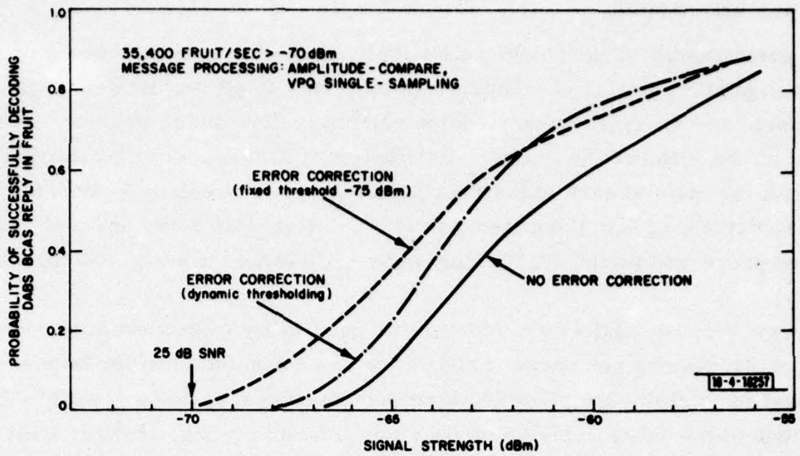


Fig. V-1. Probability of successfully decoding a DABS BCAS reply in fruit vs signal strength; effect of dynamic thresholding VPQ single sampling.

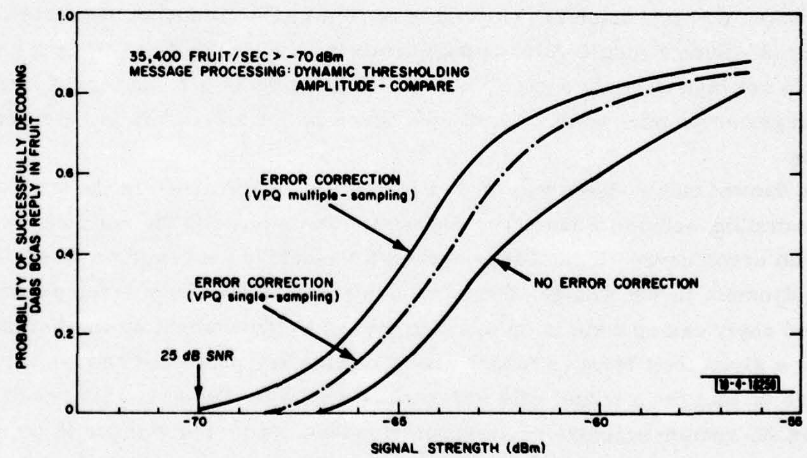


Fig. V-2. Probability of successfully decoding a DABS BCAS reply in fruit using VPQ single- and multiple-sample techniques.

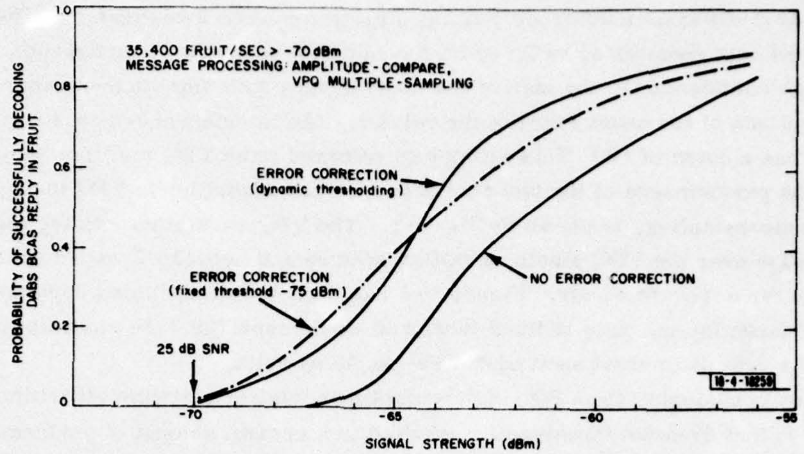


Fig. V-3. Probability of successfully decoding a DABS BCAS reply in fruit vs signal strength; effect of dynamic thresholding – VPQ multiple sampling.

dynamic threshold setting improves performance for strong signals (signals with a probability of success >0.5) and degrades performance by 1 to 2 dB for weaker signals (see Fig. V-1). Dynamic thresholding has no effect on the amplitude-compare bit declaration scheme. Thus, this degradation is the result of the VPQ single-sampling algorithm used in setting the confidence bits. The VPQ multiple-sampling confidence-setting algorithm (see 5 below) performs considerably better.

Since dynamic thresholding has no effect on bit declaration, the "no error correction" curve shown in Fig. V-1 provides a lower bound for the error correction with dynamic thresholding case.

The simulation has further shown that a reasonable technique for obtaining an amplitude estimate is to simply sample-and-hold the last preamble pulse. There was negligible improvement in overall reply processing performance by correlating amplitude samples taken from the four preamble pulses so as to obtain an interference-free amplitude estimate.

4. The Effect of Bit Declaration

In an attempt to improve overall message processing performance, several different bit-declaration and confidence-setting algorithms were investigated. Two basic bit-declaration techniques were looked at: amplitude-windowing and VPQ up/down counting. Amplitude-windowing consists of setting an amplitude window about the amplitude estimate obtained from the preamble, and declaring a bit to be a 1 if the amplitude sample of the first chip lies within the window, and a 0 otherwise. This scheme is intended to keep large interferers from "capturing" the bit declaration. VPQ up/down counting consists of adding a 1 to a counter whenever a VPQ sample is present during the first chip (maximum of eight per chip), and subtracting a 1 whenever a VPQ sample is present during the second chip. A bit is declared a 1 if the sign of the count is positive, and 0 otherwise; this scheme attempts to declare bits based on pulse width. However, in all cases, the new algorithms (amplitude-windowing, VPQ up/down counting, and minor modifications of these two basic ideas) performed only slightly better, at the expense of processor complexity, or performed more poorly. Thus, amplitude-compare is to be used in the BCAS DABS reply processor for declaring bits.

5. The Effect of Confidence Setting

Several different confidence-setting algorithms were investigated. The technique which performed best consists of VPQ up/down counting (see previous paragraph), and declaring a bit to be high confidence if: the sign of the count agrees with amplitude-compare bit decision, and the magnitude of the count exceeds the value 3. (An interference-free 1 bit has a count of +8; a 0 bit has a count of −8.) This scheme is referred to as VPQ multiple sampling. A comparison of the performance of the two confidence-setting algorithms, VPQ multiple-sampling and VPQ single-sampling, is shown in Fig. V-2. The VPQ multiple-sampling algorithm enjoys a ≈1-dB edge over the VPQ single-sampling scheme and between 2 and 4 dB improvement over the no error correction case. Figure V-2 has been drawn assuming dynamic thresholding; a similar curve for the case of fixed threshold would show the VPQ multiple-sampling scheme exhibits a 0.5-dB improvement over VPQ single sampling.

When considering the VPQ single-sampling confidence-setting algorithm, it was found (Fig. V-1) that dynamic thresholding resulted in a certain amount of performance degradation when processing the BCAS reply in the presence of fruit (ignoring multipath). Figure V-3, analogous to Fig. V-1 except for using the VPQ multiple-sampling algorithm to set confidence, shows that, not only is the performance loss from using dynamic thresholding small for weaker signals, ~0.5 dB, but dynamic thresholding results in up to 1 dB gain for stronger signals.

Because of the overall performance improvement depicted in Fig. V-2, and the fact that the algorithm can be implemented easily and inexpensively, the DABS BCAS reply processor employs the VPQ multiple-sample technique for setting confidence.

B. Active BCAS Engineering Requirement

1. Introduction

As indicated above, performance analysis of the DABS mode of an active BCAS system has shown that there is a need for parity protection of BCAS squitter transmissions. In addition, the DABS transponder used in an active BCAS installation is required to employ antenna diversity to enhance the BCAS-to-BCAS link performance in heavy ATCRBS fruit and multipath. This section summarizes the DABS mode of BCAS as reflected in the new engineering requirement.

2. DABS Mode Surveillance

a. BCAS Squitters

Except when operating in a region where BCAS squitters are locked out by ground control, all DABS transponders transmit a parity-protected squitter waveform at random intervals averaging about one second. This squitter transmission is a DABS All-Call reply which contains a 6-bit subset of the digitized altitude code in place of the DABS capability code ordinarily transmitted in an All-Call reply.

In traffic environments in which there are few DABS targets, it would be acceptable if all DABS squitters are acquired and actively tracked regardless of their relative altitude and range with respect to the protected aircraft. However, when the density of BCAS-equipped targets is high (e.g., more than 10 in a 20-nmi radius), altitude filtering and tracking of squitters are required to limit the number of DABS air-to-air interrogations, since each DABS interrogation suppresses nearby ATCRBS transponders and reduces the ATCRBS round reliability.

b. Squitter Processing

When a BCAS-equipped aircraft receives a squitter, it checks the (truncated) altitude of the target against its own altitude to determine whether the target should be ignored, immediately acquired in range, or tracked in altitude to determine if the altitude difference is decreasing at a fast enough rate to warrant range acquisition. Since it is assumed that the BCAS unit will have to operate in a relatively high-density traffic environment, the surveillance processor attempts to minimize the number of active DABS interrogations to prevent unnecessary electrical interference with the ground-based surveillance system.

The altitude of squitter transmissions is quantized to 1000-ft increments because only six bits of the pressure altitude code are available in the DABS All-Call format used for squitter transmissions. (Two bits are used for format control. The remaining data bits of the All-Call reply are reserved for the target ID. The ID is needed for interrogating the target and decoding its discrete replies, i.e., discrete replies have their parity field overlapped with the 24-bit ID. The squitter is decoded in the BCAS receiver by assuming the parity field is overlapped with an all-zero ID.)

This relatively coarse quantization of altitude requires that altitude tracking of squitter replies be accomplished over a long period by measuring the time between changes in the altitude code, and assuming that the altitude rate is constant between observed changes. Altitude rates are sufficiently slow so that tens of seconds are typically required for each 1000-ft change in the relative altitude between two aircraft. Thus by measuring the time between 1000-ft changes, the altitude rate may be approximated with sufficient accuracy to permit a rudimentary sort of altitude tracking.

c. Acquisition Processing

When the squitter processing routine determines that a target should be acquired, the target ID is placed in an acquisition queue. Once each second, as a normal part of the DABS surveillance process, the acquisition queue is examined to determine if one or more new squitters have been received. If so, bursts of up to four discrete acquisition interrogations are transmitted per target to determine the range of the target. The antenna used for the transmission of the first of these interrogations is determined by whether the target is above or below own aircraft. After each interrogation, the reply processor reports the status of the reply. If no reply is received in the listening window, additional interrogations are transmitted immediately (within the current 1-sec "scan"). Reinterrogation continues until two replies are received which correlate in range. All acquisition interrogations are transmitted at full power. The number of reinterrogations and the antenna chosen for each interrogation are automatically determined by the past interrogation and reply history. Interrogation bursts continue at 1-sec intervals until correlation is achieved, or until a 6-sec interval elapses with no correlation and no further squitter receptions from that target.

After reception of the discrete reply, the altitude is checked to verify that the target is still within the altitude threat zone. The reply correlation process assures that the reply is not a multipath reply or a reply to some BCAS acquisition interrogation. After two or more acquisition replies have satisfactorily correlated, the range of the target is tested to determine if it is in the range threat zone. If so, the target is added to the active track file. If the target is not within the range zone, a calculation is made of the minimum time required for it to penetrate this zone, and it is placed in a dormant file until that time has elapsed. While dormant, subsequent acquisition attempts are inhibited.

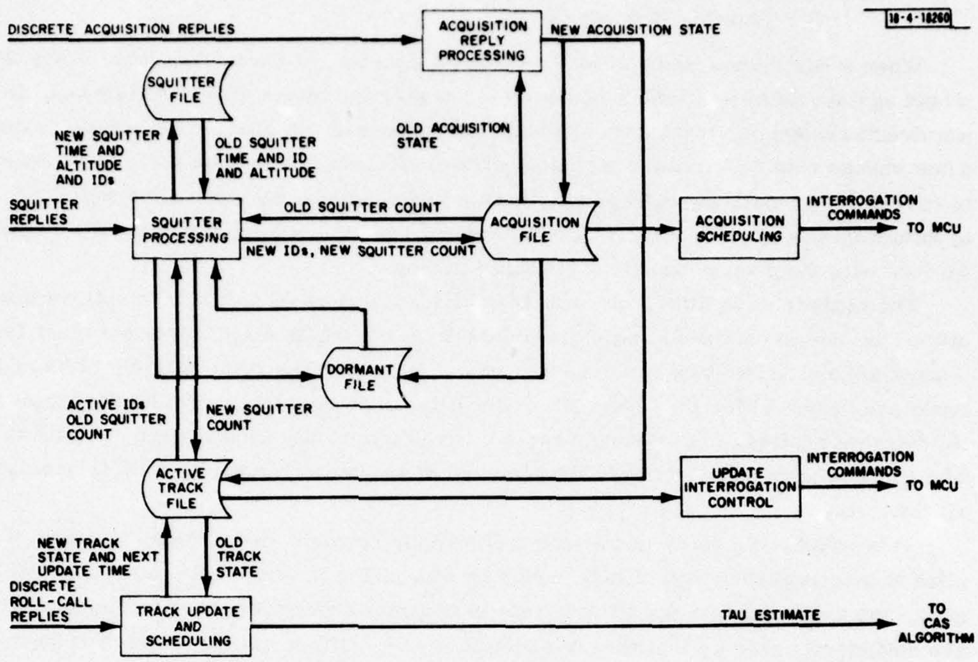


Fig. V-4. DABS processing for BCAS.

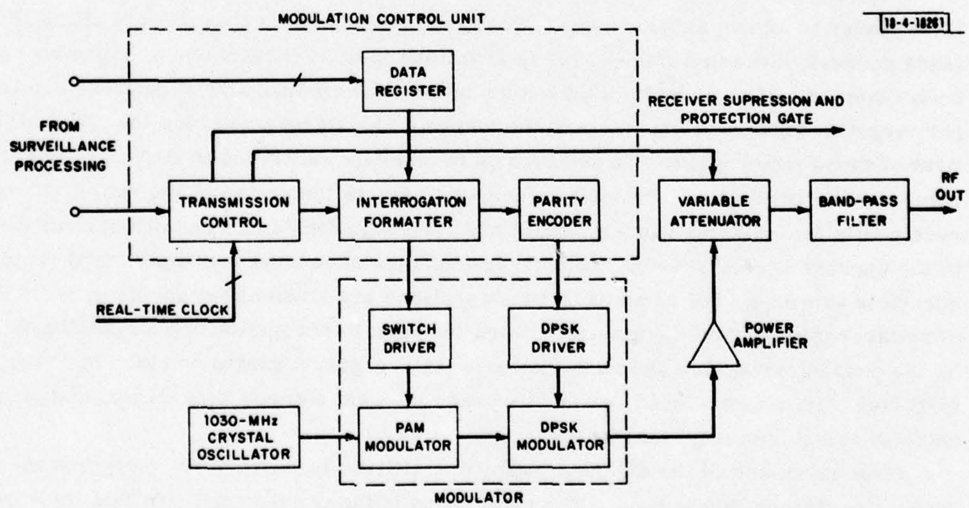


Fig. V-5. BCAS transmitter.

d. Roll-Call Surveillance

When a target is initially acquired, its ID, range, and altitude are entered into the active track file along with track firmness and history parameters which are used for track update and track drop and for the calculation of predicted range uncertainty. In addition, the acquisition routine enters a code indicating that the target is to be interrogated in the next 1-sec track-update or scan interval and a code indicating which antenna was used when the target was acquired.

Once each second, the surveillance executive schedules interrogations of all active targets in the track file. As in acquisition, bursts of interrogations are scheduled until either the maximum number of tries is reached or a valid reply is received from the target. Power programming is used to automatically determine the minimum required transmitter power required to successfully track the target. If three successive interrogations are successful, the transmit power is reduced to the next available discrete power level. If four interrogation attempts fail to elicit a reply, the transmit power is increased by one step. As in acquisition processing, automatic antenna switching and interrogation rate control are employed to minimize the number of interrogation attempts.

If a reply is not elicited from a target during a scan, the track is coasted until the next scan, and the track history and firmness parameters are appropriately updated. If a valid reply is received and altitude and range tests are passed, the target track file is updated with new predicted values of range and range rate.

e. Surveillance Software

The DABS surveillance software consists of routines which support DABS acquisition and roll-call surveillance and result in estimates of range and range rate for DABS targets. The collision avoidance logic for DABS targets is not included in this description.

Figure V-4 is a block diagram of the DABS surveillance processing software functions and files. The active track file contains targets undergoing acquisition. Once per second, an executive calls the acquisition processing and track update and scheduling functions. Unlike discrete processing, which is scheduled every second, the squitter processing routine is called by interrupt whenever a squitter reply is received. Because squitter servicing and interrogation scheduling involve random processes, BCAS interrogations will never be repeated with a fixed period from one surveillance update cycle to the next.

3. BCAS DABS Hardware

a. Transmitter and Modulator

The BCAS transmitter block diagram is shown in Fig. V-5. The transmitter hardware consists of an oscillator and modulator, a modulation control unit, a variable attenuator, and a transmitter power amplifier. Crystal control of the 1030-MHz oscillator (to ±0.01 MHz) provides a stable carrier for the DABS DPSK message. The modulator consists of a cascaded Pulse Amplitude Modulator (PAM) and Differential Phase Shift Keyed (DPSK) modulator.

b. Modulation Control Unit

The Modulation Control Unit (MCU) handles both ATCRBS and DABS interrogations, accepting control data and defining the waveform to be generated. Discrete ID and certain bits of the 56-bit data block must be input from the surveillance processor for each DABS interrogation.

The transmission control unit compares a word received from the interrogation processing function with the real-time clock to determine the exact time of transmission, and generates a gate to indicate that the interrogator is transmitting. This unit also receives a code specifying the required interrogation power level, reformatting and feeding it to the variable attenuator to control the transmitter power from interrogation to interrogation.

Control bits defining the transmission type are used to generate the required preamble field and to provide for the selection of the PAM or DPSK modulator. In addition to generating ATCRBS interrogations, the PAM modulator generates the preamble for the DABS transmission (P_1 and P_2) and turns on the carrier during the transmission of the DABS data block.

The DABS data output of the interrogation formatter is fed to the parity encoder. A data field buffer in the parity encoder receives the 56 bits containing the information content of the DABS transmission. They are converted to a serial bit stream and shifted through the parity encoder with the appropriate timing to allow the output of the encoder to directly drive the DPSK modulator.

c. Power Amplifier and Attenuator

The RF signal is amplified in a multi-stage amplifier to produce an output power of 2 kW. Filtering is provided by an external band-pass filter.

Following the power amplifier is a digital attenuator capable of handling a peak power of 2 kW. The attenuator is a high-power PIN diode switch controlled by an analog signal derived from a digital-to-analog converter. Calibration of the attenuation function is obtained from a read-only memory.

d. BCAS DABS Receiver

The BCAS DABS receiver processes the RF signal input (Σ) to the system from the top- or bottom-mounted antenna, and outputs video and quantized (two-level) video signals to the BCAS DABS reply processor as shown in Fig. V-6. Σ is input to a logarithmic amplifier/detector to produce the video signal denoted as Log $|\Sigma|$. The Log $|\Sigma|$ signal is processed by a video threshold comparator to produce the two-level quantized sum video signal denoted $Q\Sigma D$. In addition,

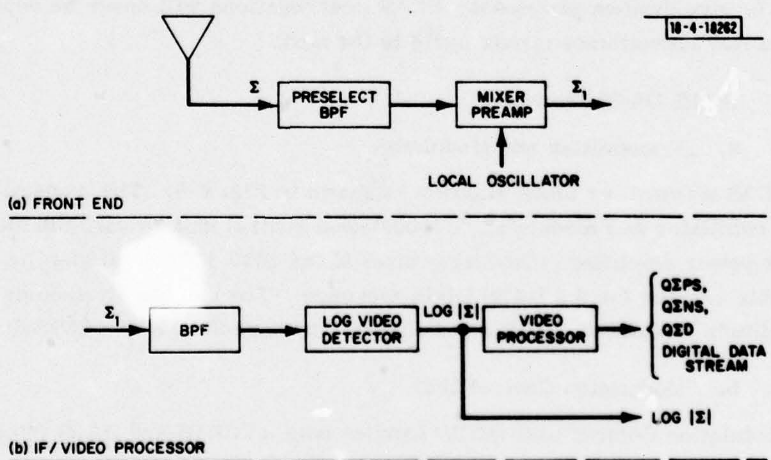


Fig. V-6. BCAS receiver.

the slope of the Log $|\Sigma|$ signal is processed by video threshold comparators to produce the quantized video signals indicating positive and negative slopes (denoted QΣPS and QΣNS).

An adaptive threshold is provided to reduce the effect of multipath on message processing. This is accomplished by referring the detection threshold to the amplitude of the last preamble pulse. Whenever the preamble is detected, the threshold is set to a value 6 dB below that pulse or set to a fixed threshold, whichever is greater. A reply-rate-dependent threshold is also provided so as not to overload the target buffer while minimizing the processing of replies due to fruit. Decreasing the receiver detection threshold will free up the target buffer by removing the more distant squitter targets from the target buffer. Reply detection on close-in targets will improve with the resulting decrease in the occurrence of preamble false alarms due to fruit.

e. BCAS DABS Processing

The BCAS DABS processing subsystem processes the receiver output signal to detect BCAS squitters and discrete replies, to determine range for discretes, and to decode message blocks for both types of replies. Its output consists of reply reports, one per successfully detected and decoded squitter reply, one per discrete roll-call interrogation (whether the reply is successfully processed or not), and one or more per discrete acquisition interval. A functional block diagram of the BCAS DABS processing subsystem is shown in Fig. V-7.

The video pulse quantizer (VPQ) operates on the three quantized video signals derived from Log $|\Sigma|$ to produce a clocked binary data stream which preserves the width of pulses with amplitudes greater than a specified threshold. The DABS preamble detector processes only the SQΣD binary data stream and produces a precisely timed trigger pulse used to determine range and to establish the timing of the data block sampling. Upon receipt of a trigger pulse denoting detection of a DABS preamble, the sampling control logic generates sequences of sampling control pulses to be used to control the instants at which the quantized video width signals and amplitude comparison signals are sampled. Upon detection of a DABS preamble, an output is generated

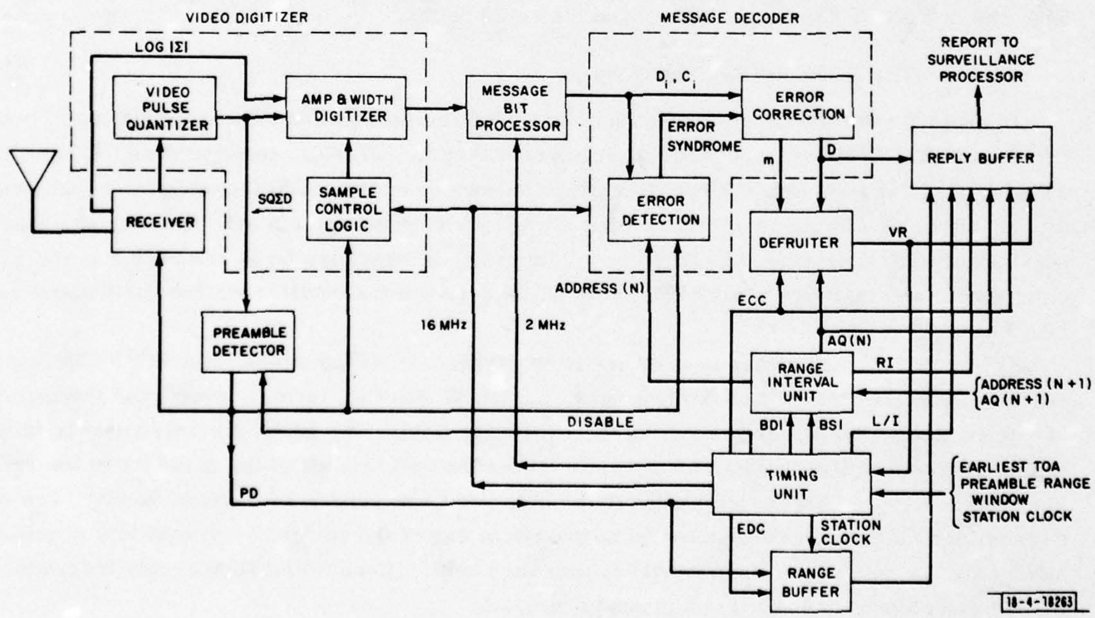


Fig. V-7. BCAS DABS reply processor.

by the quantized video width digitizer under control of the sampling control logic. The resulting output is one sample per data block chip, with the sampling instants occurring nominally at 500 nsec (8 sample intervals) after the expected leading edge of each chip, as determined from the leading-edge sample of the first preamble pulse. Data are extracted from the Log $|\Sigma|$ video input signal by comparing the amplitudes of the two chips corresponding to an information bit of the data block.

The message bit processor processes the video digitizer outputs corresponding to a sampled data block and produces a sequence of information bit decisions and a corresponding sequence of confidence bits.

Message decoding functions to check the bit decision sequence for errors by means of a parity check. If errors are detected, it uses the confidence-bit sequence to locate a burst error pattern spanning up to 24 bit decisions that would correct the message. After computing the 24-bit error syndrome, message decoding attempts to locate a correctable error burst pattern in the bit decision sequence generated by the data block processor. Finally, error correction occurs.

Replies successfully decoded by the message decoder are identified as either valid or fruit (due to either other BCAS interrogators or the DABS ground system) by the BCAS DABS defruiter. The Range Interval Unit (RIU) controls whether the BCAS DABS reply processor is in a squitter, discrete acquisition, or discrete roll-call reply mode by specifying the address used by the message decoder and the value of the acquisition flag used by the defruiter. During a discrete acquisition or squitter interval, two preambles may be detected before the message decoder has produced the reply associated with the first preamble. Thus, a range buffer must be provided capable of retaining up to two range estimates. Finally, a report is generated and stored in the reply buffer, one per successfully detected and decoded squitter reply and one or more per discrete interrogation, whether the reply is successfully processed or not.

The timing unit provides timing signals to the sampling control unit, message bit processor, and message decoder. In addition, it provides control signals to the preamble detector, the RIU, the defruiter, the range buffer, and the reply buffer.

4. The BCAS DABS Transponder

In order for the BCAS system to function effectively in an environment consisting of both DABS- and ATCRBS-equipped targets, it is necessary for all DABS transponders to cooperate with BCAS airborne units. The modifications necessary to the DABS transponder to achieve this should be as simple as possible. The BCAS DABS interrogation will be a standard DABS surveillance interrogation, identified as a unique BCAS transmission by the coding of the Reply Length (RL) and message source (MSRC). BCAS data are transmitted via the Surveillance Data (SD) field.

BCAS DABS transponder replies are of two types: BCAS squitters, and BCAS discrete replies. The squitter format is identical to the DABS All-Call format, except for the inclusion of a truncated altitude code in place of the capability field. The BCAS discrete reply is identical to the DABS surveillance reply format, except for the fact that all of the data bits in the surveillance reply format, which can ordinarily be obtained from outside of the transponder, are redefined for BCAS use. There need be no change of any of the control or format bits of this reply since only the BCAS interrogator will decode the reply. (Unsolicited DABS reply transmissions will be rejected as fruit by DABS ground sensors.)

A further requirement of all DABS BCAS transponders is that they should not reply to the BCAS ATCRBS interrogation. This interrogation is a standard ATCRBS Mode C waveform with an additional 1.6-μsec-wide P_4 pulse following P_3 by 1.5 μsec. DABS transponders must examine the duration of the P_4 pulse and withold a reply upon receipt of this interrogation.

Additional requirements are placed on those DABS trandponders which are to be installed in aircraft with active BCAS equipment on board. In order to assure a reliable air-to-air link between BCAS-equipped aircraft, it is advisable for the DABS transponder on board these aircraft to include antenna diversity capability. A modification has been made to the original DABS diversity specification to make it more suitable for the air-to-air environment, which is characterized by relatively strong multipath signals. Automatic antenna selection is performed on the basis of the relative strengths of the detected signals from the first pulse of the interrogation only if both channels simultaneously receive a valid pulse pair indicating either a possible DABS interrogation or an ATCRBS or ATCRBS/DABS All-Call interrogation. The selected antenna is then used for the reception of the remainder of the interrogation and for the transmission of the reply. If one of the two antennas receives a valid pulse pair 0.25 μsec or more in advance of the other antenna, the antenna receiving the early signal is selected regardless of the relative signal strength. When transmitting squitters, which are not generated in response to interrogations, the selected antenna is alternated from one squitter transmission to the next.

C. Air-to-Air Multipath Measurements

A basic multipath experiment (see Report No. FAA-RD-76-126) consists of sending an interrogation (20/sec rate) from the AMF aircraft, carrying the Mode D interrogator and recording equipment, to a second aircraft carrying a specially designed transponder. When an interrogation is sent, a signal is sent to the AMF to record the interrogation time and to enable the recording circuitry. Upon receipt of a Mode D interrogation, the transponder transmits four pulses with interpulse spacings of 55, 60, and 57 μsec. The first two are transmitted from a bottom-mounted antenna, and the last two from a top-mounted antenna. Replies are transmitted continuously at the proper repetition rate, the interrogations serving to synchronize the recording facility with the replies and to ensure accurate range information. When pulses at the proper frequency are received at the AMF aircraft, both top and bottom antennas are sampled and pulse amplitude and time of arrival are recorded.

Figure V-8 illustrates the raw data as recorded on the AMF instrumentation tape. E. T. is an external trigger word containing the interrogation time. The rest of the lines are pulse data words. The column labeled TOA shows the line in 1/8-μsec increments of each pulse sample. The columns labeled RCVR BOT and TOP ANT present A/D output numbers which are proportional to the pulse power received on each antenna. These numbers are processed to get signal strength in dBm. The column labeled ΔT shows the time increment between pulse samples. Once a pulse is received, it will be sampled each 1/4 μsec until the pulse strength drops below the MTL. Thus, there can be several samples per pulse depending on the received pulse width.

The samples labeled D are associated with reply pulses transmitted directly from one aircraft to the other. The samples labeled M are associated with ground-scattered multipath signals. The first subscript of the pulse type designator represents the location of the transmitting antenna while the second subscript represents the receiving antenna (four combinations possible). The direct and multipath samples are separated from samples of interference pulses, i.e., ground interrogations via time filtering techniques.

-4-19284

				TOA			RECEIVER BOTTOM ANTENNA			RECEIVER TOP ANTENNA			ΔT			
0	1	55442	60768													
0	0	0	0	55442	61223		56	0		61	0	199	5415	454188514	PULSE •	374
0	0	1	0	55442	61225	D_{BB}	56	0	D_{BT}	61	0	199	2	454188515	PULSE •	375
0	0	0	0	55442	61227		47	0		54	0	109	2	454188515	PULSE •	376
0	0	1	0	55442	61356		26	0		20	0	154	129	454188532	PULSE •	377
0	0	0	0	55442	61358		29	0		20	0	109	2	454188532	PULSE •	378
0	0	0	0	55442	61360		19	0		13	0	109	2	454188532	PULSE •	379
0	0	0	0	55442	61364	M_{BB}	19	0	M_{BT}	16	0	75	4	454188533	PULSE •	380
0	1	0	0	55442	61366		13	0		16	0	64	2	454188533	PULSE •	381
0	1	0	0	55442	61376		16	0		17	0	64	10	454188535	PULSE •	382
0	1	0	0	55442	61663		56	0		61	0	199	287	454188569	PULSE •	383
0	0	1	0	55442	61665	D_{BB}	56	0	D_{BT}	61	0	199	2	454188570	PULSE •	384
0	0	0	0	55442	61667		47	0		54	0	64	2	454188570	PULSE •	385
0	0	0	0	55442	61796		27	0		17	0	177	129	454188586	PULSE •	386
0	0	0	0	55442	61798		28	0		17	0	177	2	454188586	PULSE •	387
0	0	0	0	55442	61804	M_{BB}	21	0	M_{BT}	14	0	64	6	454188588	PULSE •	388
0	1	0	0	55442	61806		13	0		9	0	64	2	454188588	PULSE •	389
0	1	0	0	55442	62143		59	0		63	0	199	337	454188630	PULSE •	390
0	0	1	0	55442	62145	D_{TB}	59	0	D_{TT}	63	0	199	2	454188630	PULSE •	391
0	0	0	0	55442	62147		51	0		55	0	64	2	454188630	PULSE •	392
0	0	0	0	55442	62599		60	0		63	0	199	452	454188686	PULSE •	393
0	0	1	0	55442	62601	D_{TB}	59	0	D_{TT}	63	0	199	2	454188687	PULSE •	394
0	0	0	0	55442	62603		51	0		55	0	109	2	454188687	PULSE •	395
0	0	1	0	55442	64590		20	0		19	0	334	1987	454188936	PULSE •	396
0	0	1	0	55442	64595		8	0		5	0	87	5	454188936	PULSE •	397

Fig. V-8. Multiple-experiment raw data (sample).

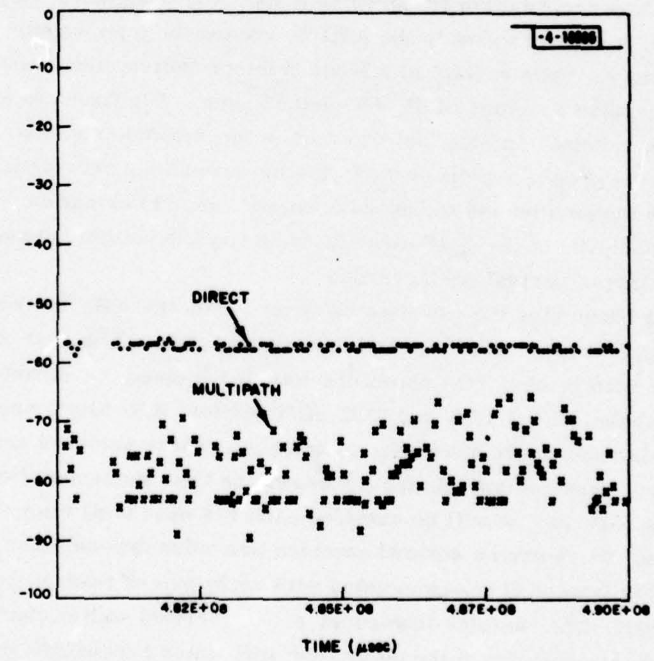


Fig. V-9. Average signal strength vs time: city residential, 9500 ft altitude, bottom-to-bottom antennas.

Once a complete four-pulse reply is received and the associated multipath signals are recognized, the pulse time, amplitude, and antenna combination information is further processed to generate statistical summaries and various plots.

Four primary plots display multipath amplitude:

(1) Raw direct and multipath signal strength vs time for short periods of time (Fig. V-9).

(2) Variation in average direct and multipath signal strength for an entire flight (Figs. V-10 through -13).

(3) Signal-to-multipath ratio (SMR) maximum, average, and minimum values over short time intervals for an entire flight (Figs. V-14 through -15).

(4) Signal-to-multipath ratio cumulative distributions (Figs. V-16 and -17).

Each of these plots may be made for each of the four antenna combinations.

Preliminary results indicate that the bottom-to-bottom antenna combination is far more susceptible to multipath interference than bottom-to-top or top-to-top antenna combinations. As would be expected, the degree of multipath reflection as a function of antenna combination depends on the surface scatter properties. The contrast is illustrated in Figs. V-10 and -12. In both figures, the aircraft were at 9500 feet (nominal) and flying along diverging flight paths. Figures V-10 and -11 data were taken over a city and residential area, while Figs. V-12 and -13 data were taken over the ocean (sea state 1). Figures V-10 and -12 are associated with the bottom-to-bottom antenna combination, while Figs. V-11 and -13 are associated with the top-to-top antenna combination. The SMR cumulative distributions in Figs. V-16 and -17 for CONUS and oceanic terrains, respectively, bring out two important points. First, the SMR curve shifts to the right, i.e., SMR tends to increase for the bottom-to-bottom combination as the surface becomes rough in comparison to a calm sea. Secondly, the SMR distribution for the top-to-top antenna combination shifts slightly to the left for a rough surface indicating that while the individual multipath contributions are smaller, due to a smaller reflection coefficient, the top antennas pick up more multipath because the scattering area for a rough surface is much larger than for a smooth surface. Also to be noted is that for a rougher surface the SMR distribution for the top-to-top combination is not as dramatic an improvement over the bottom combination as for a smoother surface.

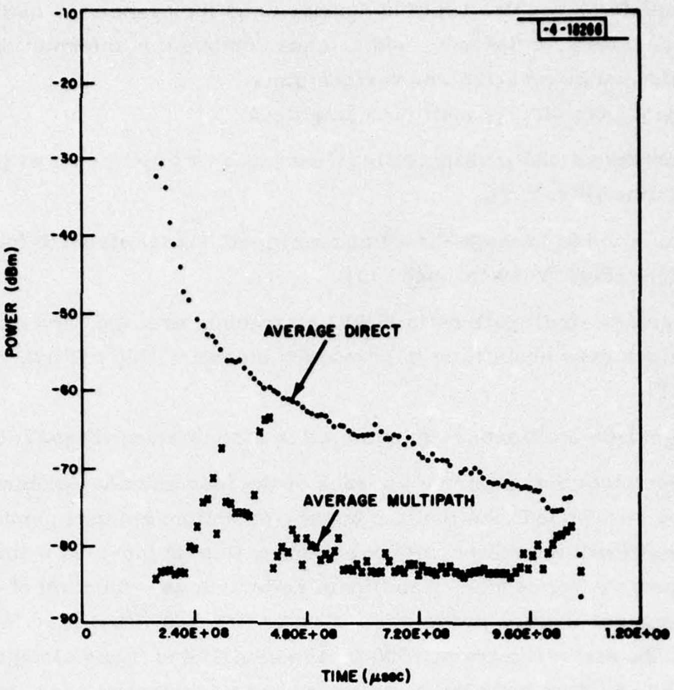


Fig. V-10. Average signal strength vs time: city residential, 9500 ft altitude, bottom-to-bottom antennas.

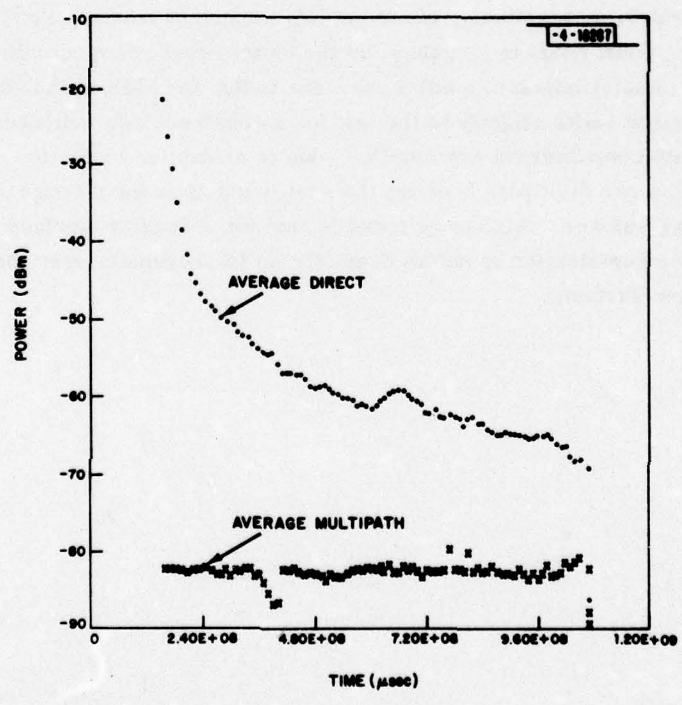


Fig. V-11. Average signal strength vs time: city residential, 9500 ft altitude, top-to-top antennas.

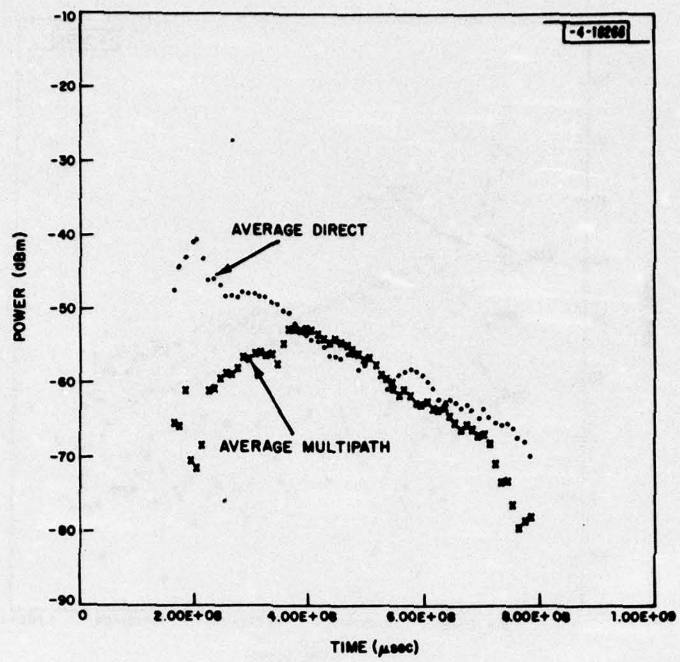


Fig. V-12. Average signal strength vs time: ocean (sea state 1), 9500 ft altitude, bottom-to-bottom antennas.

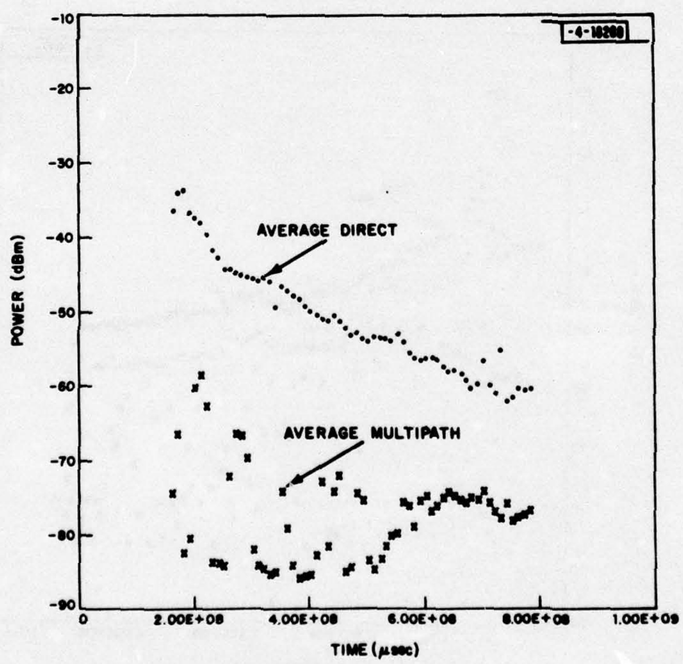


Fig. V-13. Average signal strength vs time: ocean (sea state 1), 9500 ft altitude, top-to-top antennas.

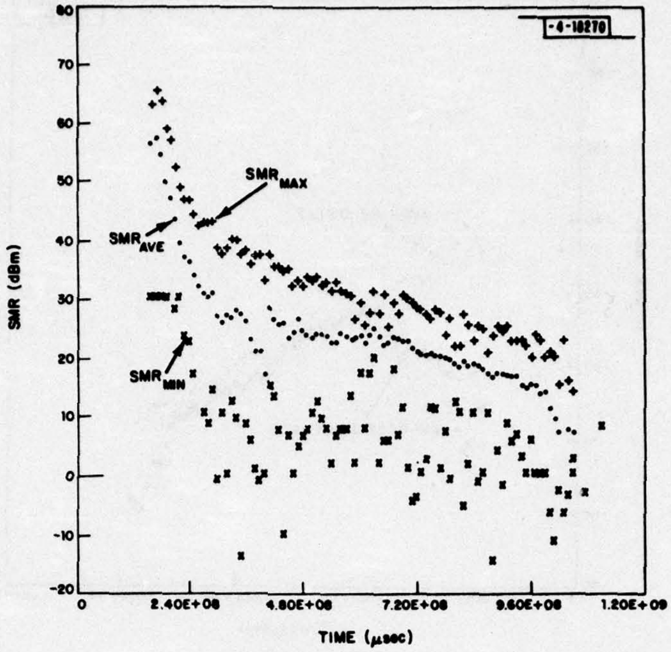


Fig. V-14. Average signal/multipath ratio vs time: city residential, 9500 ft altitude, bottom-to-bottom antenna.

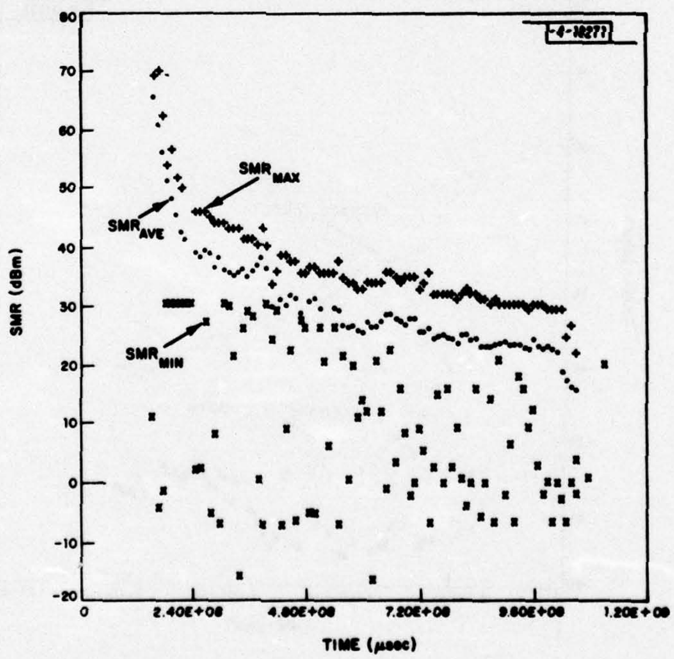


Fig. V-15. Average signal/multipath ratio vs time: city residential, 9500 ft altitude, top-to-top antenna.

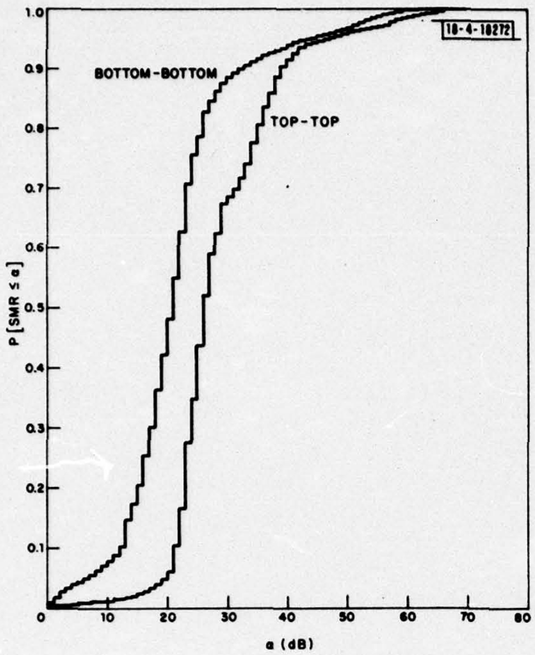
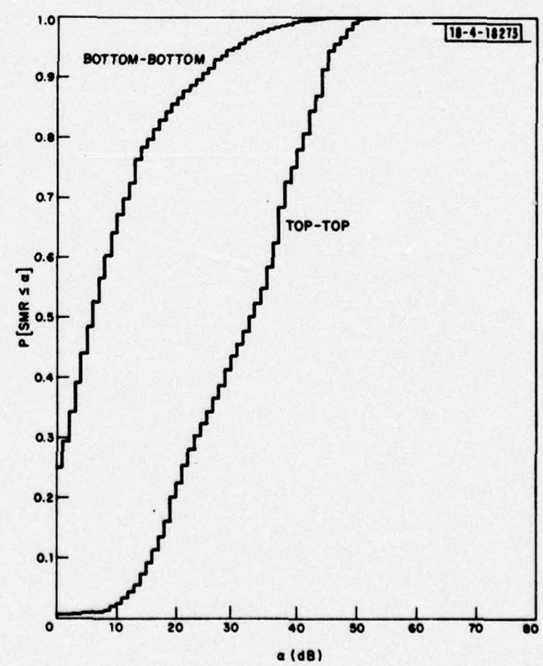


Fig. V-16. Signal/multipath ratio cumulative distribution for all multipath delays; 9500 ft altitude, city residential, top-to-top and bottom-to-bottom antennas. (Aircraft separation to 20 nmi.)

Fig. V-17. Signal/multipath ratio cumulative distribution for all multipath delays; 9500 ft altitude, ocean (sea state 1), top-to-top and bottom-to-bottom antennas. (Aircraft separation to 20 nmi.)



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VI. ARIES

A. Equipment and Software Status*

The designs for all the Lincoln Laboratory designed components except the interfaces to the computer's data bus and the ARIES tester have been completed; interface designs should be completed shortly. By the end of the next reporting period, it is expected that all the above components will have been assembled in equipment racks and hardware debugging will have been started.

An Eclipse (Data General) computer with 32K words of memory (16-bit words), a 10-Mbyte disk, tape drive, and teletype has been purchased for the ARIES project. This machine has been interfaced with a Versatec line printer. Other machine options and devices with which the system is equipped are a writeable control store (allowing user-written microcode), a real-time clock, and a synchronous modem interface. A board which provides a modem interface for data formatted in Production Common Digitizer (PCD) format has been obtained, and this will be used in ARIES to provide simulated radar data to the DABS sensor.

Software development is proceeding with skeleton versions of the disk input task and the real-time clock handler already programmed. An assembly language version of the interrogation processing task has been programmed prior to implementing the kernel of this task in microcode.

The programs which convert the master traffic model tape into ARIES input format have been completed in their initial form. In addition to format conversion, these programs perform coordinate conversions and generate various data fields (Mode A code, DABS ID, pilot acknowledgement, etc.) which are not specified on the master model tape. These bits are normally set by default algorithms in the program, but the user can override the default values by means of card inputs. This program currently runs under the Lincoln Laboratory IBM 370 time-sharing system, but it is anticipated that in the future it will be converted to run under 370 batch and/or on the Eclipse system.

B. Controller Design

CAT and FAT controllers sequence controlled and fruit replies to six target generators. The CAT controller receives the controlled replies from the ARIES computer, and the FAT controller receives the fruit replies from the Random Process Generator (RPG). The fruit parameter for the RPG can be also selected by the ARIES computer through the FAT controller. (See block diagram on p. 42 of the 1 January 1976 QTS.)

Figure VI-1 is a simplified block diagram of the ARIES target controller. It is designed around the Advanced Micro Devices 2901 bipolar bit-slice microprocessor. Its features include many high-speed microprogrammable arithmetic and logical functions. With N of these devices connected in parallel, a $4 \times N$-bit microprocessor can be implemented. To be compatible with the ARIES 16-bit computer; four 2901's were used to construct the ARIES target controller.

The sequence of microinstructions for the microprocessor is controlled by the AMD-2909 sequencer. This device is also a 4-bit-wide slice. Three 2909's were used to allow the addressing of up to 4096 microprogram steps.

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*The design-construction status information given here refers to elements of a DABS system test facility described in the 1 January 1976 DABS QTS. It is suggested that the reader refer to the ARIES description given on pp. 41 to 45 of that issue for necessary background.

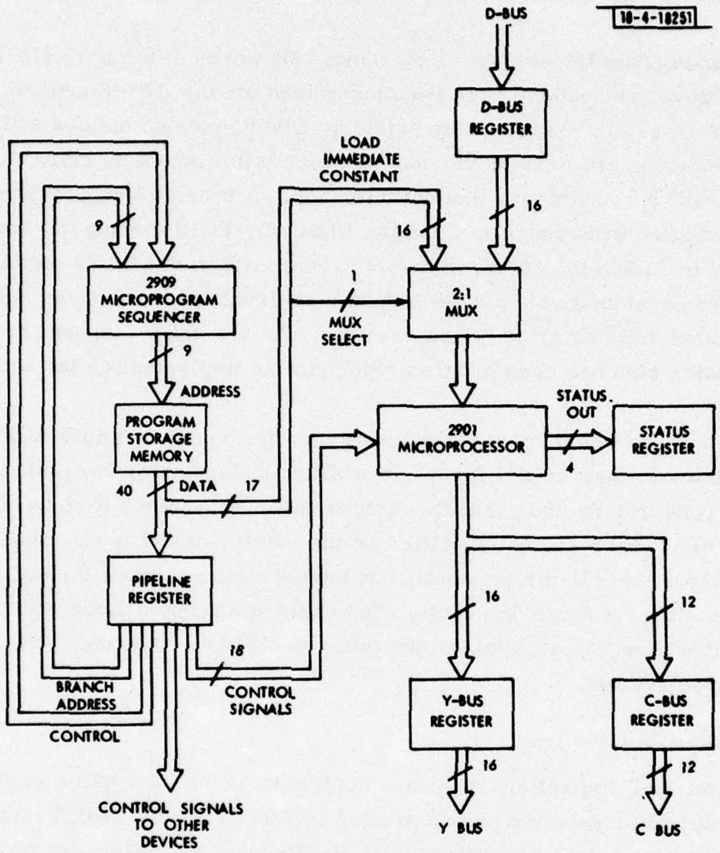

Fig. VI-1. ARIES target controller.

The microinstructions for the target controller are stored in the program storage memory (ROM). It is made up of five 8-bit read-only memories. Pipeline registers were used to buffer the data from the ROMs, so that the next microinstruction can be fetched while the current one is being executed. Each microinstruction supplies all necessary control signals for the 2901's and other devices.

The CAT and FAT controllers are implemented in the same manner utilizing the above processor. The only difference is in the programs resident in the ROMs.

The controllers communicate with the Target Generators, the ARIES computer, and the RPG over the D-bus, the Y-bus, and the C-bus. The D-bus and the Y-bus are used to transfer the input and output data, respectively, while the C-bus is used to send control signals.

The algorithms used to sequence the controlled replies and the fruit replies are shown in Figs. VI-2 and -3.

Since ARIES will handle only ATCRBS fruit, each fruit reply from the RPG will be only four words long. Whereas in the case of the controlled reply, it can be four or ten words long depending on whether it is an ATCRBS or DABS reply, respectively. Figures VI-4 and -5 illustrate the reply format.

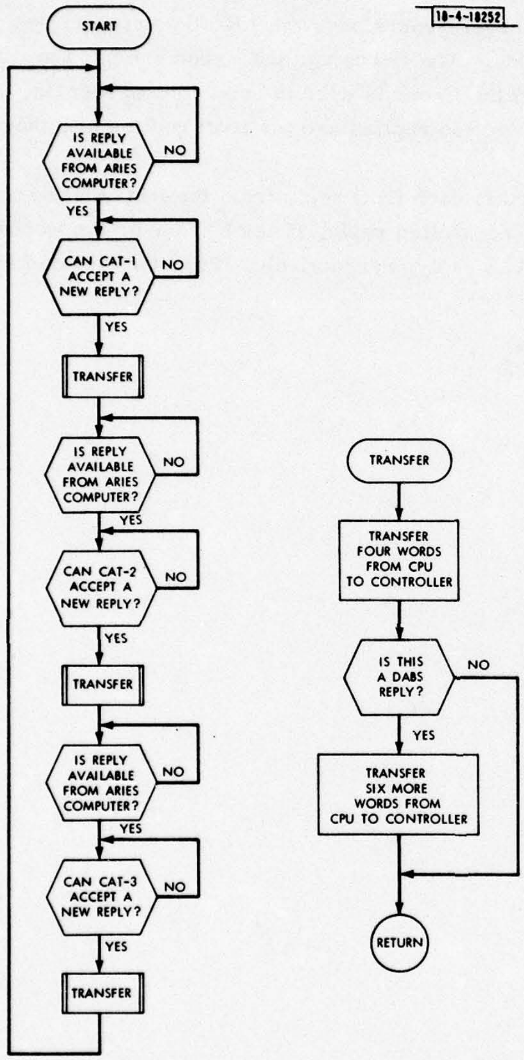

Fig. VI-2. ARIES CAT–controller flow chart.

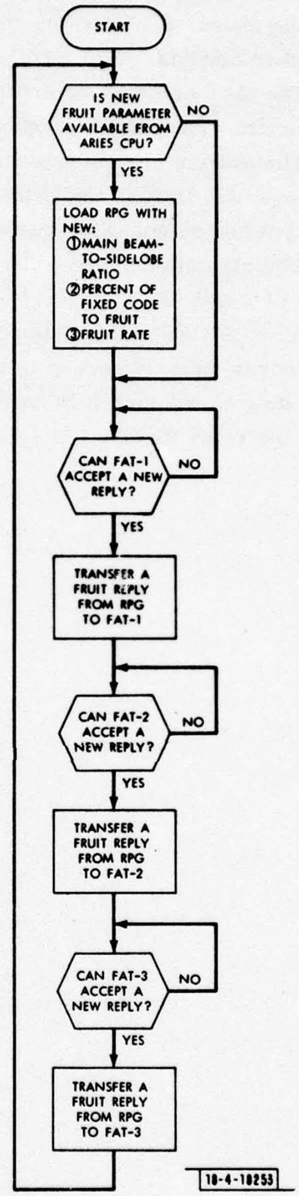

Fig. VI-3. ARIES FAT–controller flow chart.

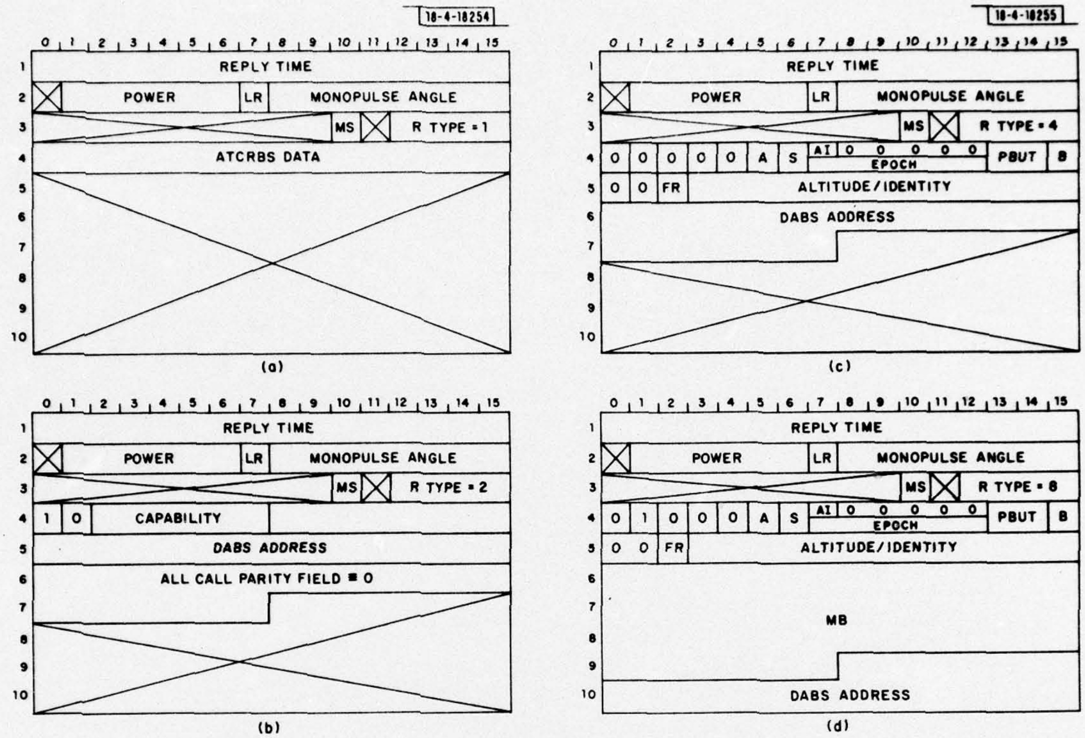

Fig. VI-4. Reply formats.

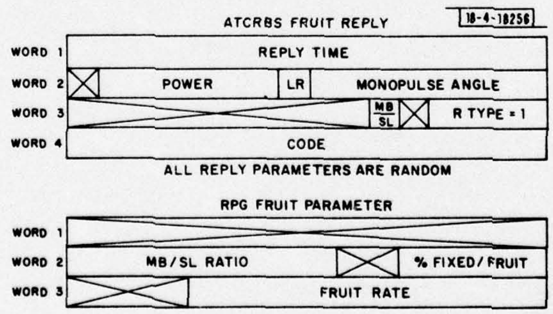

Fig. VI-5. Fruit reply format and RPG fruit parameter.

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VII. EXPERIMENTAL AND TEST FACILITIES

A. DABSEF

1. Activities Supported

Approximately 80 percent of the effort at DABSEF was devoted to the collection and reduction of experimental data from IPC flights and TMF field experiments. The remaining time was devoted to AMF/BCAS flights and Bendix transponder checkout.

Three types of TMF data tapes are processed at DABSEF as follows:

> DABS Experiments (Free Run Mode).– The input tape consists of data recorded after preamble detection of a DABS reply. During the processing of this tape the following functions are performed: message decoding, error correction, mainlobe or sidelobe reply flagging, and comparison of messages received with messages expected. The above process produces print and tape (DFLAG tape) output. The tape is forwarded to the IBM 370 for further processing.
>
> TMF Analysis (Edge Events Mode).– Edge Events are normally processed with RSLS on. The output tape created contains mainbeam replies only. This reply tape is processed to create an SDP-formatted TMF tape so that programs developed for SDP may be used for analysis. If antenna pattern data are desired, the processing is done with RSLS off, and no SDP-formatted tape is required.
>
> TMF Monopulse Calibration.– A comparison of the calibration data and reference monopulse table is made.

B. Avionics

Prototype DABS diversity transponders (Bendix) now installed in all flight test aircraft have permitted collection of TMF experimental data at field sites (see Sec. VII-C) and airborne diversity performance data at DABSEF (see Sec. II-C-2). In-flight operation of these transponders at near-MUSL thresholds and under realistic ATCRBS traffic and fruit environments has disclosed several performance shortcomings. Some of the malfunctions originated as a result of problems in interpreting design specifications and some due to inadequate unit test; some were discovered only as the result of hitherto inexperienced uplink environments. Specification changes and clarifications to prevent misinterpretation of design and performance requirements have been recommended where necessary.

One of the more serious performance shortcomings was uncovered during test flights against TMF in the Philadelphia area as reported in Sec. II-A. An unacceptably low level of link reliability at certain ranges was found to be due to suppression of both ATCRBS and DABS channels for 30 to 35 μsec following receipt of an ATCRBS suppression pair. The original specification did not permit such action, and Bendix has been requested to initiate a retrofit program to correct this fault.

Measurement in search for the cause of the reduced link reliability also showed that when locked out to ATCRBS, the transponder still examines ATCRBS-like pulse pairs, but being locked out, does not reply. In the examination process, busy with ATCRBS, the decoder misses valid DABS interrogations, especially when strong pulses position themselves in front of DABS

interrogations such as to form ATCRBS pairs with P_1, P_2, or the data block of DABS. The solution is a design which prevents decoding attempts for locked-out transmissions. Specifications have been changed to assure such design.

Present avionics activity is directed at additions and modifications required to accommodate BCAS. Provisions are being made to permit BCAS ancillary equipment to be added to DABS transponders by connections to the SM interface port. This will permit independent construction of DABS transponders and BCAS equipment and will also permit changes in the BCAS format without making transponder changes.

C. TMF

Experiments employing the TMF were performed at Clementon, N.J., Philadelphia International Airport, and at Los Angeles International Airport as shown in Table VII-1.

Results of most of the below experiments will be reported in subsequent QTSs following data reduction and analysis at DABSEF.

TABLE VII-1

TMF EXPERIMENTS

Experiment	Clementon, N.J. (to 25 July)	Philadelphia, Pa.* (2 Aug.–8 Sept.)	Los Angeles Intn'l† (18 Sept. on)
TMF-centered circular flights for site characterization		x	x
Radial flights of DABS-equipped aircraft to evaluate the DABS processor		x	x
DABS-equipped aircraft surface taxiing experiment		x	
Low-altitude coverage of FAA specified fixes and way points near Philadelphia	x	x	
Experiment to determine the effect of I^2SLS in eliminating of false targets		x	
Target-of-opportunity recordings simultaneously with ARTS recordings to compare performance	x	x	x
Dedicated aircraft flights near high-density airports in the LA Basin to record data for use in evaluating the IPC algorithms			x

* TMF sited 2500 ft east of ARTS radar.

† TMF sited as shown in Fig. VII-1.

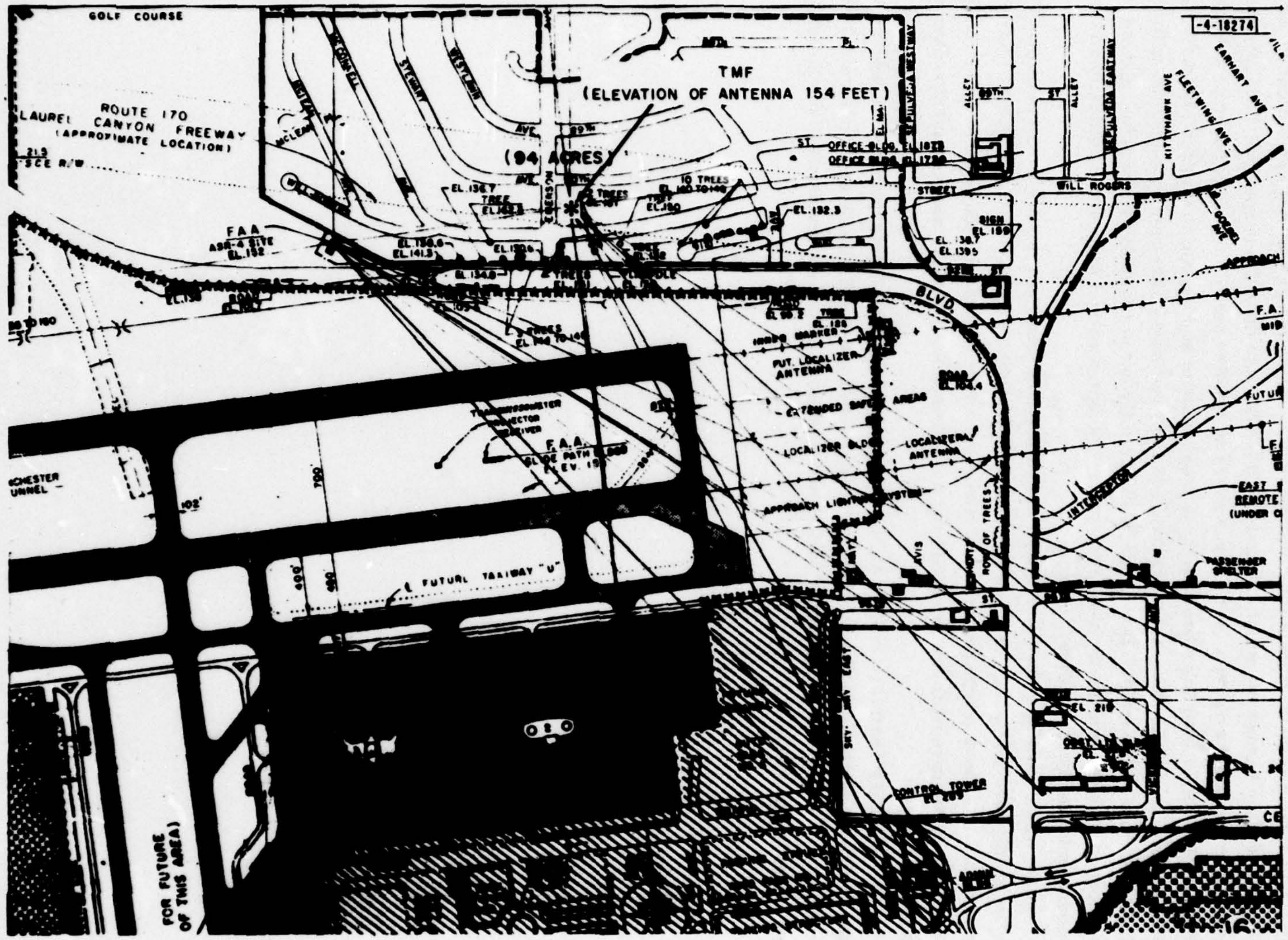

Fig. VII-1. TMF site at Los Angeles International Airport.

D. AMF

The primary use of the AMF this quarter was to measure air-to-air multipath in the BCAS program (measurement results given in Sec. V-C). Some effort was required to debug the multipath measuring hardware, which consists of the AMF and the CTU (Crosslink Transponder Unit), carried in a second aircraft. It was necessary to resolve some burn-out problems arising from the use of a single frequency band for both transmission and reception on each aircraft. Some effort was also expended to reduce an appreciable hardware error rate having to do with the digital portion of the AMF. This effort was partially but not entirely successful, and we have proceeded with the multipath measurements, relying instead on software complexity and an inherent redundancy in the data.

Late in the quarter, the AMF was flown to the Los Angeles area for a series of missions: 1030 uplink coverage measurements for the passive-BCAS program; 1090 ATCRBS fruit measurements to assess a top-antenna fruit reduction effect at high altitudes; 1030 uplink environment measurements over the LA Basin for comparison with similar measurements taken six months earlier.

Certain AMF hardware modifications are planned for the coming quarter. These will permit DABS-mode replies to be recorded for a series of air-to-air DABS experiments. The hardware error rate problem mentioned above will also be attacked by revisions to the buffer memory and sample control logic.

ABBREVIATIONS AND ACRONYMS

ABIL	Airborne Beacon Interrogator Locator
AC	Air Carrier
A/C	Aircraft
ACS	All-Call to Subset
ACS	Acquisition and Control System (part of SEL-86 computer)
A/D	Analog to Digital
ADC	Air Defense Center
ADIZ	Air Defense Identification Zone
AGL	Above Ground Level
AIMS	Compatible DOD-ATC Beacon System
ALEC	Altitude Echo
AMF	Airborne Measurements Facility
AMPS	ATCRBS Monopulse Processing Subsystem
APG	Azimuth Pulse Generator
ARB	Ambiguity Resolution Bit
ARIES	Aircraft Reply and Interference Environment Simulator
ARINC	Aeronautical Radio, Inc.
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASCII	American Standard Code for Information Interchange
ASR	Airport Surveillance Radar
ATA	Air Transport Association
ATAS	Aircraft Tone and Audio System
ATC	Air Traffic Control
ATCAC	Air Traffic Control Advisory Committee
ATCBI-X	ATCRBS Beacon Interrogator (Model X)
ATCRBS	Air Traffic Control Radar Beacon System
Au	Angle Unit
BCAS	Beacon Collision Avoidance System
BDAS	Beacon Data Acquisition System
BRP	Beacon Reply Processor
C	Climbing
CA	Controller Acknowledgment
CAS	Collision Avoidance System
CAT	Controlled ARIES Targets
CD	Common Digitizer
CDM	Cockpit Display Monitor
CF	Close Fit (algorithm)
CIDIN	Communications ICAO Data Interchange Network
COMM-n	DABS Message Type Designation (n = A, B, C, or D); See FAA-RD-74-62
CONUS	Conterminous United States

CP	Collision Point
CPME	Calibration Performance Monitoring Equipment
CPU	Central Processing Unit
CPV	Correlation Preference Value (NAS)
CRT	Cathode Ray Tube
CRW	Close Range Window
csc^2	Cosecant Squared
CTU	Crosslink Transponder Unit
CW	Continuous Wave
D'	Descending
DABS	Discrete Address Beacon System
DABSEF	DABS Experimental Facility
DABSIM	DABS Simulation (software program)
DABSLST	DABS Performance Measurement Program (software)
DAS	Digital Acquisition System (ARTS)
dBI	Decibels With Respect to "Isotropic
dBm	Decibels With Respect to 1.0 Milliwatt
DCAS	DABS-Based CAS
DCFSK	Direct-Coupled Frequency-Shift Keying
DF	Direction Finding
DG	Design Gain
DIM	DABS Interrogation Modulator
DME	Distance Measuring Equipment
DMID	Downlink Message Identification (No.)
DOD	Department of Defense
DOT	Department of Transportation
DOT	Range Times Range Rate (vector "dot" product)
DPSK	Differential Phase-Shift Keying
DRP	DABS Reply Processor
DSF	Digital Simulation Facility (at NAFEC)
DTSD	DABS Traffic Situation Display
DV&R	Design Validation & Refinement
DYNO	A High-Efficiency Interrogation Scheduling Algorithm
ECAC	Electromagnetic Compatibility Analysis Center
EER	Envelope of Error
ELM	Extended Length Message
EN	Envelope of Nulls
E-SCAN	Electronically Scanned Antenna
ER	Engineering Requirement
ERP	Effective Radiated Power
ESC	Experimental Sensor Configuration

FA	Fade Allowance
FAA	Federal Aviation Administration
FAT	Fruit ARIES Targets
FPWI	Flashing PWI (indication)
FR	Full Ring (algorithm)
FSK	Frequency-Shift Keying
GA	General Aviation
GCAS	Ground-Based Collision Avoidance System
GTC	Gain Time Control
HSC	High-Speed Channel (SEL-86 computer)
IAC	Instantaneous Airborne Count
IAR	Interrogation Arrival Rate
ICAO	International Civil Aviation Organization
ICR	Integrated Cancellation Ratio
ID	Identification
IFF	Identification Friend or Foe
IFR	*Instrument Flight Rules*
IISLS	Improved Interrogation Sidelobe Suppression
ILS	Instrument Landing System
I/O	Input/Output
IPC	Intermittent Positive Control
IRO	Increasing Range Order
LAX	Los Angeles International Airport
LEA	Link Elevation Angle
LED	Light Emitting Diode
LOS	Line of Sight
LR	Link Reliability
LSB	Least Significant Bit
LSI	Large Scale Integrated (-tion)
LTC	Link Test Configuration
Mb/S	Megabits/Second
MCU	Modulator Control Unit
MIL	Military
MILS	Microwave Instrument Landing System
MLS	Microwave Landing System
MNAS	Maximum Number of Sensors
MS	Maximum Number of Sectors
MSI	Medium Scale Integrated (-tion)
MSL	Mean Sea Level
MTDS	Military Tactical Data Systems
MTL	Minimum Triggering Level
MUDSL	Minimum Usable DABS Signal Level

NAFEC	National Aviation Facility Experimental Center
NAS	National Aviation System
NDA	No Data Available
NIKE	United States Army Anti-Aircraft System
NOZ	Normal Operating Zone
NRTCP	New-Real-Time Control Program
NRZ	Non Return to Zero
NRZI	Differentially Encoded NRZ (flux reversal equals "1")
NTDS	Naval Tactical Data System
OAT	Outside Air Temperature
ORW	Open Range Window
OSEM	Office of Systems Engineering Management
PA	Pilot Acknowledgment
PAM	Pulse Amplitude Modulation
PAR	Pulse Arrival Rate
PCA	Positive Control Area
PCD	Production Common Digitizer
PEM	Position Entry Module
PIAC	Peak Instantaneous Airborne Count
PLE	Pseudo Leading Edge
PLL	Phase Lock Loop
PLRACTA	Position Location, Reporting and Control of Tactical Aircraft
PPM	Pulse Position Modulation
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PROM	Programmable Read Only Memory
PRP	Pulse Repetition Period
PSK	Phase-Shift Keying
PWI	Pilot Warning Indicator
QSLS	Quadrature (or Quantized) Sidelobe Suppression
QTS	Quarterly Technical Summary
RAM	Random Access Memory
RAS	Readout; Aircraft State
RBTF	Radar Beacon Test Facility (at NAFEC)
RCC	Regional Control Center
RDJ	Reply Delay Jitter
RIANG	Rhode Island Air National Guard
RIU	Range Interval Unit
RMSE	Root Mean Square Error
ROM	Read-Only Memory
RPG	Random Process Generator

RSLS	Receive Sidelobe Suppression
RT	Round Trip
RTCP	Real-Time Control Program
Ru	Range Unit
S&C	Surveillance and Communication
SAR	Suppression Arrival Rate
SAW	Surface Acoustic Wave
SCP	Surveillance and Communication Processor
SDC	System Development Contractor
SDP	Sensor Demonstration Program
SEC	System Engineering Contractor
SEL	System Engineering Laboratory, Inc.
SIF	Military IFF
SIR	Signal-to-Interference Ratio
SLS	Sidelobe Suppression
SM	Short Message
SMR	Signal-to-Multipath (Signal) Ratio
SNR	Signal-to-Noise Ratio
SPI	Special Pulse Identification
SPM	System Program Manager
SPWI	Steady PWI (indication)
SQV	Sampled Quantized Video
SRDS	System Research and Development Service
SS	Sum of Squares
SSF	System Support Facility (at NAFEC)
STC	Sensitivity Time Control
SWD	Sliding Window Detector
TACAN	Military Aircraft Navigation System (Providing Range and Bearing from Station)
TAD	Technical Acknowledgment, Downlink
TATF	Terminal Automation Test Facility (at NAFEC)
TAU	Technical Acknowledgment, Uplink
TCA	Terminal Control Area
TCR	Transmit Control Register
TDP	Technical Development Plan
TMF	Transportable Measurements Facility
TOA	Time of Arrival
TOD	Time of Day
TSC	Transportation Systems Center, DOT, Cambridge, Mass.
TTL	Transistor-to-Transistor Logic
TWG	Transmit Waveform Generator
UMID	Uplink Message Identification

VFR	Visual Flight Rules
VOR	Very High Frequency Omnirange (Provides Bearing Data)
VORTAC	Combined VOR and TACAN Facility
VPQ	Video Pulse Quantizer
V/STOL	Vertical/Short Takeoff and Landing
ZFLAG/ FLAGSTAT	ATCRBS Performance Measurement and Diagnostic Program (software)
ZRT	Zero-Range Trigger

DABS DOCUMENTS ISSUED BY LINCOLN LABORATORY

(Available from National Technical Information Service, Springfield, Virginia 22151)

Quarterly Technical Summaries

FAA-RD-72-44	QTS 1	1 April 1972	Development of a Discrete Address Beacon System
FAA-RD-72-76	QTS 2	1 July 1972	Development of a Discrete Address Beacon System
FAA-RD-72-117	QTS 3	1 October 1972	Development of a Discrete Address Beacon System
FAA-RD-73-12	QTS 4	1 January 1973	Development of a Discrete Address Beacon System
FAA-RD-73-48	QTS 5	1 April 1973	Development of a Discrete Address Beacon System
FAA-RD-73-101	QTS 6	1 July 1973	Development of a Discrete Address Beacon System
FAA-RD-73-165	QTS 7	1 October 1973	Development of a Discrete Address Beacon System
FAA-RD-74-8	QTS 8	1 January 1974	Development of a Discrete Address Beacon System
FAA-RD-74-85	QTS 9	1 April 1974	Development of a Discrete Address Beacon System
FAA-RD-74-136	QTS 10	1 July 1974	Development of a Discrete Address Beacon System
FAA-RD-74-167	QTS 11	1 October 1974	Development of a Discrete Address Beacon System
FAA-RD-75-4	QTS 12	1 January 1975	Development of a Discrete Address Beacon System
FAA-RD-75-67	QTS 13	1 April 1975	Development of a Discrete Address Beacon System
FAA-RD-75-114	QTS 14	1 July 1975	Development of a Discrete Address Beacon System
FAA-RD-75-166	QTS 15	1 October 1975	Development of a Discrete Address Beacon System
FAA-RD-76-10	QTS 16	1 January 1976	Development of a Discrete Address Beacon System
FAA-RD-76-82	QTS 17	1 April 1976	Development of a Discrete Address Beacon System
FAA-RD-76-126	QTS 18	1 July 1976	Development of a Discrete Address Beacon System
FAA-RD-76-174	QTS 19	1 October 1976	Development of a Discrete Address Beacon System

Project Reports

FAA-RD-72-7	ATC-8	24 January 1972	Interrogation Scheduling for the Discrete Address Beacon System	E. J. Kelly
FAA-RD-72-30	ATC-9	12 April 1972	Final Report, Transponder Test Program	G. V. Colby E. A. Crocker
FAA-RD-72-84	ATC-12	14 August 1972	A Comparison of Immunity to Garbling for Three Candidate Modulation Schemes for DABS	D. A. Shnidman
FAA-RD-72-77	ATC-13	14 August 1972	Parallel Approach Surveillance	J. B. Allen E. J. Denlinger
FAA-RD-72-100	ATC-15	29 November 1972	The Influence of Surveillance System Parameters on Automated Conflict Detection and Resolution	J. W. Andrews G. Prado
FAA-RD-73-126	ATC-19	17 October 1973	Interrogation Scheduling Algorithms for a Discrete Address Beacon System	A. Spiridon A. D. Kaminsky
FAA-RD-74-4	ATC-20	28 January 1974	The Effects of ATCRBS P_2 Pulses on DABS Reliability	W. H. Harman D. A. Shnidman
FAA-RD-74-20	ATC-22	19 February 1974	Summary of Results of Antenna Design Cost Studies	J-C. Sureau
FAA-RD-73-160	ATC-25	28 November 1973	DABS/ATCRBS Transponder Bench Testing Program	J. R. Samson J. D. Welch E. R. Becotte E. A. Crocker H. D. Schofield
FAA-RD-74-17	ATC-27	1 March 1974	A Summary of the DABS Transponder Design/Cost Studies	T. J. Goblick P. H. Robeck
FAA-RD-74-142	ATC-29	13 December 1974	"DABS Timing: Clocks, Synchronization and Restart"	E. J. Kelly
FAA-RD-73-175	ATC-30	9 November 1973	Provisional Signal Formats for the Discrete Address Beacon System	P. R. Drouilhet Editor
FAA-RD-74-62	ATC-30 Rev. 1	25 April 1974	Provisional Signal Formats for the Discrete Address Beacon System (Revision 1)	P. R. Drouilhet Editor
FAA-RD-74-5	ATC-31	13 February 1974	Report on DABS/ATCRBS Field Testing Program	J. R. Samson, Jr. E. A. Crocker
FAA-RD-74-21	ATC-32	4 February 1974	The Effect of Phase Error on the DPSK Receiver Performance	D. A. Shnidman
FAA-RD-74-63	ATC-33	25 April 1974	Provisional Message Formats for the DABS/NAS Interface	D. Reiner H. F. Vandevenne

FAA-RD-74-63A	ATC-33 Rev. 1	10 October 1974	"Provisional Message Formats for the DABS/NAS Interface"	D. Reiner H. F. Vandevenne
FAA-RD-74-64	ATC-34	25 April 1974	Provisional Data Link Interface Standard for the DABS Transponder	G. V. Colby P. H. Robeck J. D. Welch
FAA-RD-74-83	ATC-83	24 May 1974	Provisional Message Formats and Protocols for the DABS IPC/PWI Display	P. H. Robeck J. D. Welch
FAA-RD-74-84	ATC-36	20 May 1974	Provisional Message Formats and Protocols for the DABS 32-Character Alphanumeric Display	J. D. Welch G. V. Colby
FAA-RD-74-144	ATC-37	15 January 1975	An Analysis of Aircraft L-Band Beacon Antenna Patterns	G. J. Schlieckert
FAA-RD-74-145	ATC-38	13 December 1974	Further Studies of ATCRBS Based on ARTS-III Derived Data	A. G. Cameron
FAA-RD-74-162	ATC-40	4 March 1975	DABS Uplink Encoder	J. R. Samson
FAA-RD-74-186	ATC-41	28 April 1975	DABS Link Performance Considerations	G. J. Schlieckert
FAA-RD-74-189	ATC-42	18 November 1974	"DABS: A System Description"	P. R. Drouilhet
FAA-RD-74-197	ATC-43	8 January 1975	DABS Channel Management	E. J. Kelly
FAA-RD-75-75	ATC-44	16 May 1975	Model Aircraft L-Band Beacon Antenna Pattern Gain Maps	D. W. Mayweather
FAA-RD-75-8	ATC-45	16 May 1975	Network Management	H. F. Vandevenne
FAA-RD-74-210	ATC-46	June 1975	Plan for Flight Testing Intermittent Positive Control	J. W. Andrews J. F. Golden J. C. Koegler A. L. McFarland M. E. Perie K. D. Senne
FAA-RD-75-23	ATC-47	4 April 1975	Scale Model Pattern Measurements of Aircraft L-Band Antennas	K. J. Keeping J-C. Sureau
FAA-RD-75-61	ATC-48	12 September 1975	DABS Downlink Coding	J. T. Barrows
FAA-RD-75-62	ATC-49	25 July 1975	DABS Uplink Coding	J. T. Barrows
FAA-RD-75-91	ATC-50	17 July 1975	Impact of Obstacle Shadows on Monopulse Azimuth Estimate	A. Spiridon
FAA-RD-75-92	ATC-51	20 February 1976	DABS Sensor Interactions with ATC Facilities	D. Reiner H. F. Vandevenne

FAA-RD-75-93	ATC-52	12 March 1976	DABS Modulation and Coding Design – A Summary	T. J. Goblick
FAA-RD-75-112	ATC-53	3 February 1976	Summary of DABS Antenna Studies	J-C. Sureau
FAA-RD-75-113	ATC-54	2 February 1976	Design Validation of the Network Management Function	P. Mann H. F. Vandevenne
FAA-RD-75-145	ATC-56	14 November 1975	Discrete Address Beacon System (DABS) Test Plan for FY 1976	W. H. Harman D. Reiner V. A. Orlando
FAA-RD-76-22	ATC-57	16 March 1976	IPC Design Validation and Flight Testing – Interim Results	J. W. Andrews J. C. Koegler
FAA-RD-75-233	ATC-60	25 March 1976	The Airborne Measurement Facility (AMF) System Description	G. V. Colby
FAA-RD-76-2	ATC-61	9 June 1976	Empirical Characterization of IPC Tracker Performance Using DABS Data	J. Leeper A. Tvirbutas
FAA-RD-76-2	ATC-62	23 March 1976	Beacon CAS (BCAS) – An Integrated Air/Ground Collision Avoidance System	V. A. Orlando J. D. Welch

Technical Notes

1972-38	4 December 1972	The Use of Supplementary Receivers for Enhanced Positional Accuracy in the DAB System	E. J. Kelly
1973-7	9 February 1973	A Maximum-Likelihood Multiple-Hypothesis Testing Algorithm, with an Application to Monopulse Data Editing	E. J. Kelly
1973-48	26 September 1973	An Optimum Interference Detector for DABS Monopulse Data Editing	R. J. McAulay T. P. McGarty
1973-44	18 December 1973	Azimuth-Elevation Estimation Performance of a Spatially Dispersive Channel	T. P. McGarty
1974-7	25 February 1974	Models of Multipath Propagation Effects in a Ground-to-Air Surveillance System	T. P. McGarty
1974-12	12 March 1974	False Target Elimination at Albuquerque Using ARTS-III Software	A. G. Cameron
1975-6	17 July 1975	Effects of Local Terrain and Obstacles Upon Near Horizon Gain of L-Band Beacon Antennas	A. Spiridon
1975-11	25 March 1975	The Statistical Characteristics of Diffuse Multipath Radiation and Its Effect on Antenna Performance	T. P. McGarty